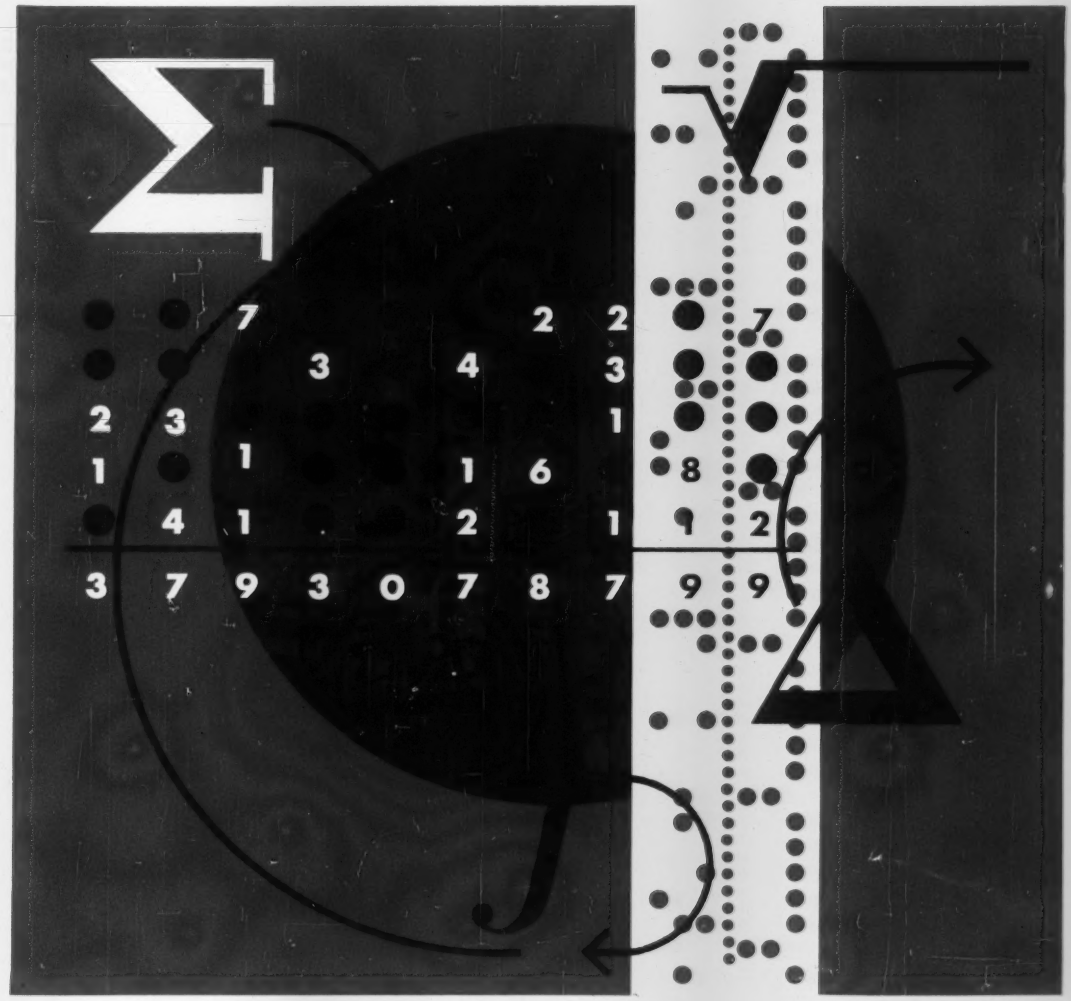
INSTRUMENTS AND CONTROL SYSTEMS

INCLUDING: INSTRUMENT MANUFACTURING • JOURNAL OF THE SCMA • SIMULATION COUNCIL NEWSLETTER



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DECEMBER 1959

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Data Analysis By Digital Computer	*1836*

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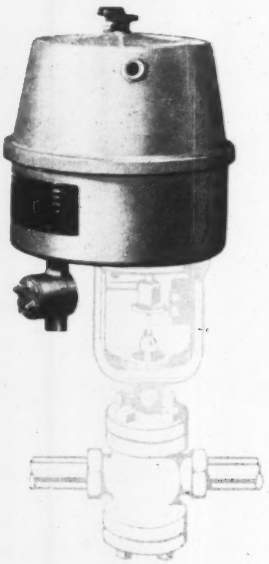

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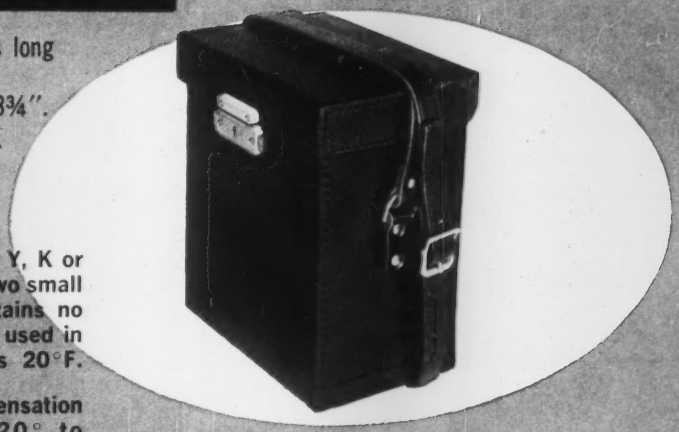

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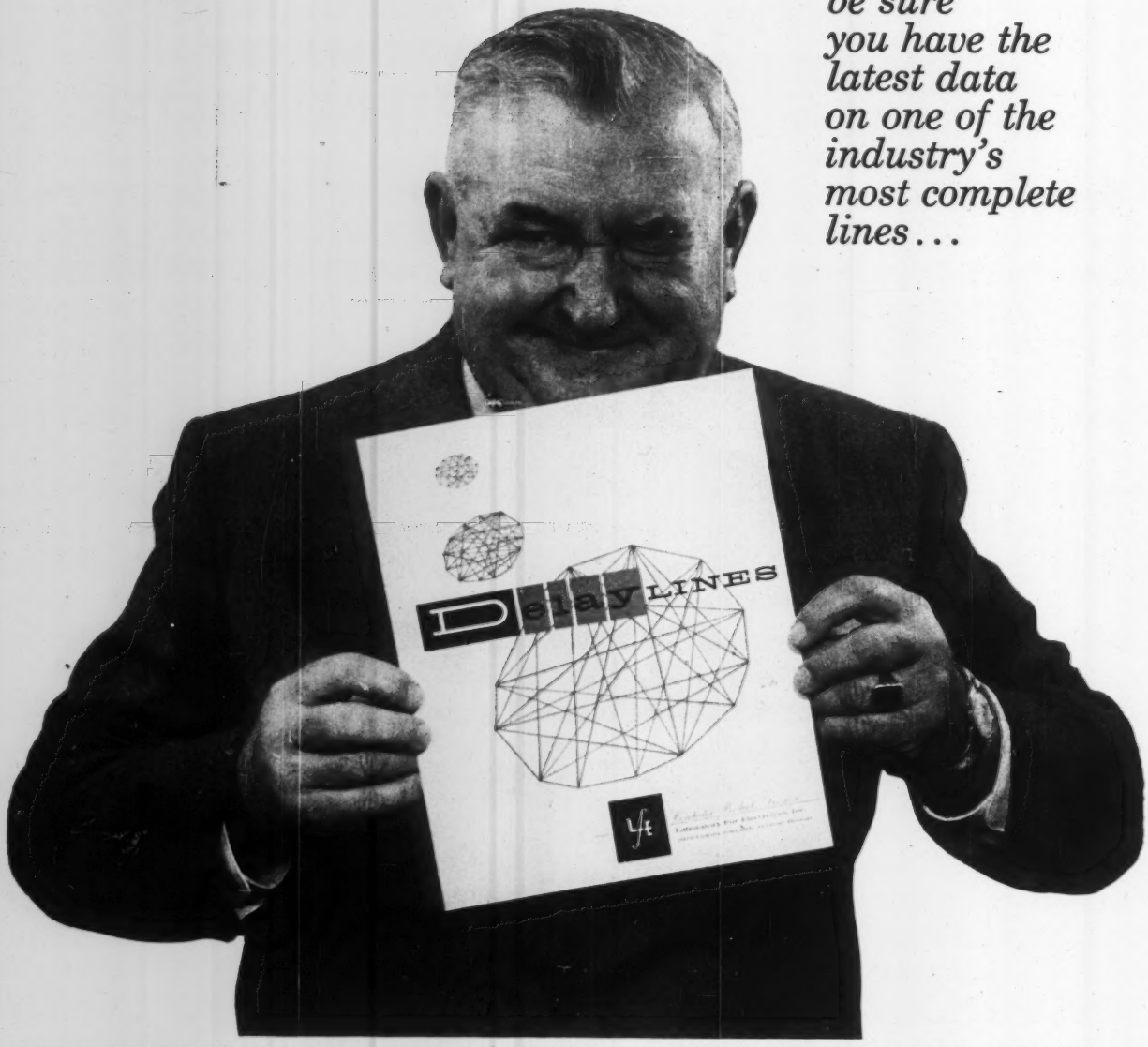

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Formerly INSTRUMENTS and AUTOMATION

DECEMBER 1959

VOLUME 32 NUMBER 12

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EDITORIAL

Happy New Year!, 1813

FEATURE ARTICLES

Computer Uses, 1816

REVIEW of many available types and their specific applications

Performance of a Solid-State Process Computer-Logger, 1820

JOSEPH A. REINE, JR.—factual record of pioneering installation of a solid-state logger computer

Natural-Gas-Dispatching Computer, 1824

BILL KARCHER and HUGH JACOBSON—describes system with computer for on-line control plus off-line calculations

Digital Control Computers, 1828

GERHARD L. HOLLANDER—review of fundamental requirements of on-line real-time control computer

Computer Control Philosophy, 1830

CLIFFORD E. MATHEWSON and BYRON WHITE discuss cost and definition of on-line process computer

Features of Digital Computers, 1832

ROBERT MCNAUGHTON—a human must make decisions for a desk size computer, but a large scale computer is capable of making decisions without help

Logical Design For Batch Process With Alarm, 1834

SEQUENCE of opening and closing valves can be logically charted for batch-type production

Dynamic Data Analysis by Digital Computer, 1836

J. E. WESTWICK—discusses considerations required in using digital computer for instrumentation data analysis

Data Loggers, 1841

M. H. ARONSON—concluding series begun last month on great variety of types and sizes of data loggers

Electronic Circuitry, 1848

M. H. ARONSON and CHARLES F. KEZER—oscillator tests temperature coefficient of coils; stereo amplifier uses new pentode-triode tube; one-shot multivibrator uses new pnpn trigistor

Process Control Systems, 1850

FRED D. MARTON—automatic acid packaging machine uses dip-tube level-control system; chocolate tempering cycle control; non-hazardous humidity control for explosive atmospheres by wet-and-dry bulb

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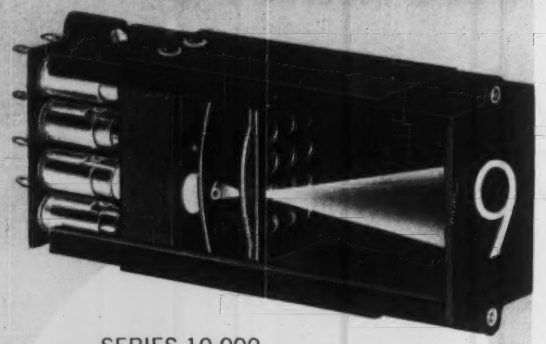
SAVE TIME—MONEY—LABOR



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INSTRUMENTS AND CONTROL SYSTEMS

VOL. 32 No. 12 DECEMBER, 1959

PRINT ORDER THIS MONTH: 35,000

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The Journal of THE SOUTHERN CALIFORNIA METER ASSOCIATION

Problems and Answers in the Design of Computer Control Systems, 1854

S. M. ROBERTS and T. M. STOUT—questions that arise in discussion and design of closed-loop computer control systems, involving theory and technique, dollars and practice

THE SIMULATION COUNCIL NEWSLETTER

Computer Installation and Checkout, 1861

Checkout Procedures, 1864

GEDA Checkout, 1866

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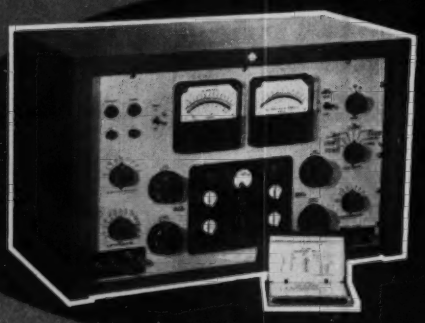
from
Instrument Calibration
HEADQUARTERS



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CIRCLE 6 ON READER-SERVICE CARD

to the editor

Editor, I&CS:

I very much appreciated the article POWER PLANT CONTROL VALVES, by T. Y. Mullen in the September issue. It is a well-thought-out article which shows how a little foresight and knowledge of the process can build controllability into a servo loop. When Mr. Mullen talks about choosing a valve characteristic to even out changes in pressure drop as in a level controller, he is making an inexpensive valve do the same job as a more expensive proportional controller with reset.

One topic that Mr. Mullen might have expanded on is the common one of two control valves in series which occurs whenever you have a steam heated device with a control valve on the inlet and a steam trap on the outlet.

I hope you will continue to publish articles as well-written as this one.

L. A. Schafer
Professional Engineer
Cromwell, Conn.

Editor, I&CS:

Mr. Lou Rogers of Union Carbide Corporation in South Charleston is a member of our Advisory Committee on instrument mechanics and electronics. We are developing a new program to fit into the several new high schools being planned in this county for construction soon. In discussing our problem with Mr. Ralph Webb and Mr. Ivan Thomas, they came up with the very appropriate suggestion that you be contacted relative to material that you have already prepared. I believe this material has appeared in *Instruments and Control Systems* magazine.

Any material of this nature that you would have to assist in the planning of our vocational and technical programs would be greatly appreciated.

Henry E. Knight, Director
Adult & Vocational Education
Kanawha County Schools
Charleston, W. Va.

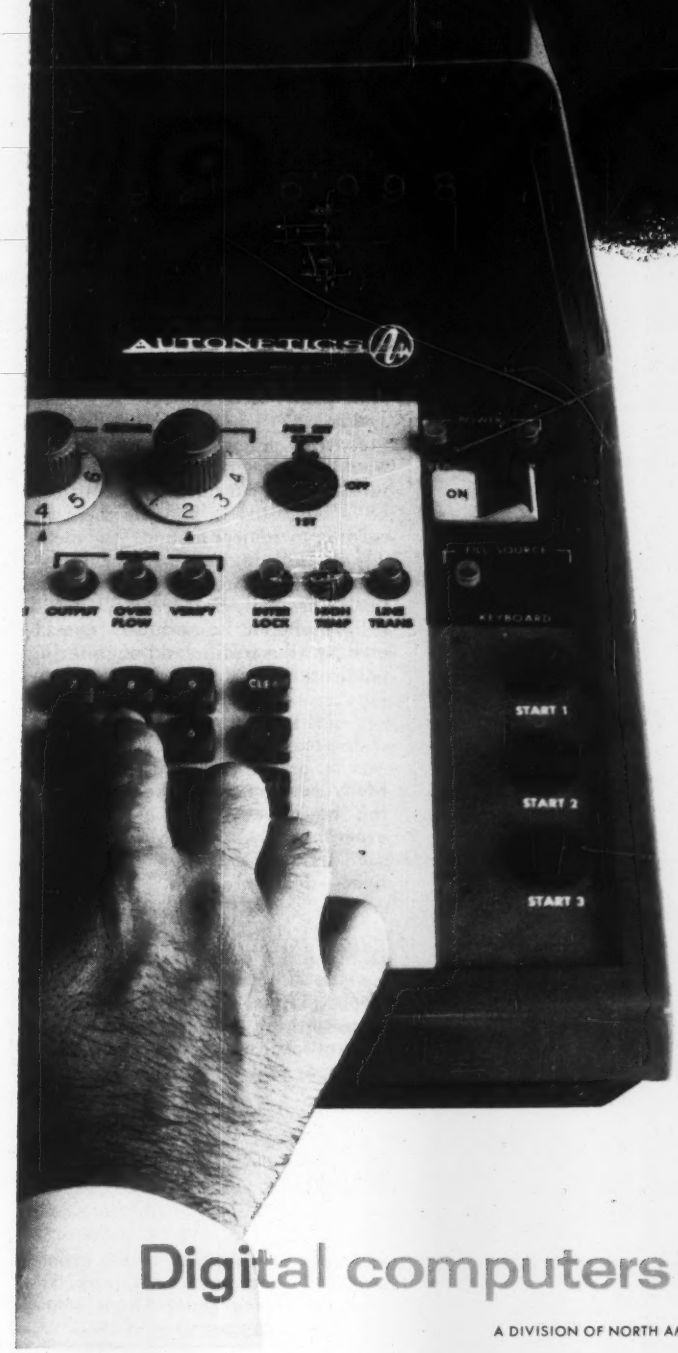
Editor, I&CS:

In your "Electronic Circuitry for Instruments & Equipment", 3rd printing, Sept., 1958, you use this spelling

0110 1001 1001 1000

RECOMP

THINKS IN "BITS" BUT TALKS YOUR LANGUAGE



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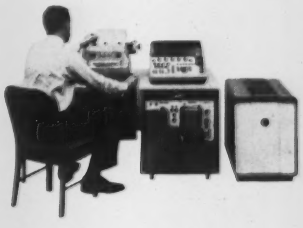

Digital computers by Autonetics
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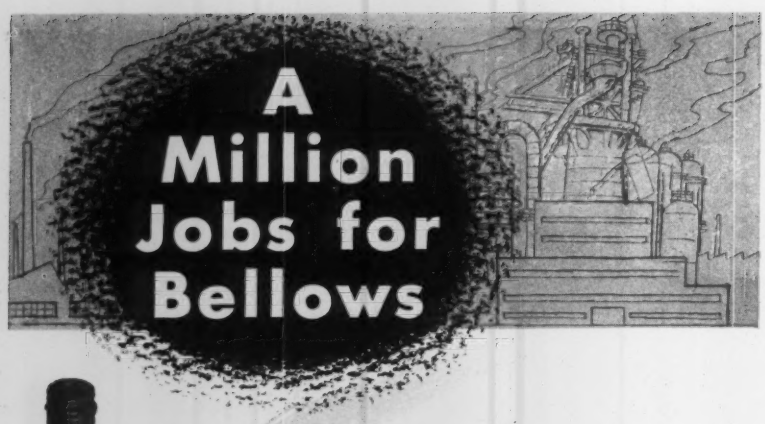

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CIRCLE 7 ON READER-SERVICE CARD

LETTERS —CONTINUED

"sinoidal". I am unable to find the word in technical or common dictionaries, or in manuals on waves, or electrical dictionaries.

I presume it means the same as "sinusoidal", and that you have taken the privilege of spelling it that way to correspond with your own style. It is not in the index.

James E. Kreiss
Sacramento 19, Calif.

The editor-in-chief at the time the book originally was written—Major M. F. Behar—was an etymological purist who objected to sinusoidal on the basis that it refered to a "sinus" rather than a "sine." Our publications have given up the fight in this instance and we use the familiar sinusoidal term.

Editor, I&CS:

I would like to recommend that any two articles published in your magazine should not appear on the same page nor on the reverse side of a page.

If this policy were followed it would then be an easy task for the subscriber to cut out only the articles he is interested in and file them according to subject matter. The method of inserting advertisements between articles is used by the publication *Chemical Engineering*, and I believe should be seriously considered by all scientific and engineering publications.

Lacy E. Johnson, Jr.
General Electric Company
Atlanta, Ga.

Many readers have requested that this be done—so we are doing it experimentally, starting with this issue. Readers who want this to continue—drop us a note.

Editor, I&CS:

After almost 3 yrs. as Phila. Educ. Comm. Chmn. I entered the field of education full time. I find this battle of hardware vs theory going on everywhere, as well as in my own mind!

Benjamin E. DeRoy
Temple University
Technical Institute
Phila., Pa.

Editor, I&CS:

Please send reprints of the articles printed in *Instruments & Control Systems* regarding public high school courses in physics. One of these was

in your February 1959 issue and another on page 375-8 of the March 1959 number.

I have recently had occasion to read some of the material developed by the Physical Science Study Committee (first administered by M.I.T. but now by Educational Services, Inc.) and believe that they have produced much more than "lots of wooden blocks" (page 377, March 1959 *I&CS*.)

From discussion with one of the teachers who is using their course in a high school in this area, it appears that above-average students find the new approach challenging and thought provoking, but below-average boys and girls have difficulty in "keeping up." It may be that junior high science courses can include more hardware and technology than they have hitherto. Although university professors have taken the initiative in this project they have worked closely with public and private secondary school teachers, and changes are bound to be made to improve teaching techniques as the results of the new course come in.

I am sure you will find that their emphasis on simple, low cost equipment is intended to encourage home experimentation by the students and to give teachers with limited budgets as good an opportunity to "get across" their ideas as the teachers in large schools with an abundance of fine equipment.

I agree with your thoughts regarding the essential differences between universities and high schools and believe that considerable cooperation between representatives of the two teaching staffs will be required to develop an outstanding physics course.

Robert F. Metcalf, Jr.
Massachusetts Society of Professional Engineers, Inc.
Boston, Mass.

The nation's problem is that not enough students are attracted to science and engineering. A "tougher" physics course will only repel greater numbers of students from science! The MIT cure here will only intensify the disease.

Editor, I&CS:

We have been investigating the problem of weight flow measurement for about five years. Recently we were asked to provide a low priced weight flow computer for the General Electric Missile and Space Vehicle Department in Philadelphia. This unit was designed and built

RAMBLINGS ON INSTRUMENTATION

INTER OFFICE MEMO

FROM: Chief Analytical Engineer

TO: V. P. Marketing

SUBJECT: Hays Thermal Conductivity Analyzer

More in sorrow than in anger I wish to report a disquieting conversation with one of YOUR salesmen, a Melvin Somebody who stumbled into our department apparently by mistake. I took the occasion to ask him in a dignified manner what applications he was selling for the Hays T.C. Analyzer. Eyebrows upraised, he queried, "T.C.?"

"Yes--T.C.," was my restrained reply.

"Terra Cotta? Tinker to Chance? Tres Chic?"

I did not blow my top but replied with simple dignity that "T.C." stood for Thermal Conductivity, a fact I thought was well known in what passes for our sales organization. At this point your man Melvin had the effrontery to pat me lightly on the head and wander off, muttering that he had to work on his swindle sheet.

Mind you, I'm not saying this character necessarily represents the prevailing ignorance of this fine Hays product. But--it certainly seems that intensive education is called for!

Actually there are at least 31 applications for the Condu-Therm, including H_2, He, SO_2, CS_2, butane and benzine!

And isn't it just remotely possible that somewhere, someday a potential user might be interested in a Thermal Conductivity Analyzer with Electric Humidity Compensation?--a major breakthrough!

You will remember that, in times past, you have implied (not too subtly) that our staff tends to be slightly technical in discussing product performance.

Now, while I seriously doubt that this Melvin could understand roller skates, I am going to attempt an explanation of the Hays Electric Humidity Compensation in terms so simple there should be no reason why almost any salesman couldn't understand it.

As you know, variations in water vapor content in the gas being analyzed produce erroneous analysis since results are usually required on a dry basis. This error can be simply stated in a specific analysis as

$$\% \text{ Error} = \frac{\left[Z - Z\left(\frac{100-W}{W}\right)\right]100}{Z}$$

(Where W=% water vapor
Z=% gas being analyzed)

After exhaustive research, we have evolved a unique method of compensating for this: a water vapor sensitive element whose resistance varies as the water content of the gas. The Variable resistance introduced into the measuring circuit automatically compensates the analysis results.

As for other features, our Condu-Therm Analyzer has divided flow assembly, high speed of response, simple zero check, corrosion-resistant construction, no moving parts and almost no maintenance...more features than any customer has a right to expect and far more than your men could remember anyway.

P.S.--Let's get the word out! Why not offer our Bulletin 59-B641 in one of those peculiar "Ramblings" ads. (I presume they're supposed to be ads.)

P.P.S.--I hope this doesn't sound bitter.

Growing Pains

A problem encountered in a growing company such as ours is keeping our national sales force fully up-to-date. We've initiated a solution by appointing two regional sales managers with a combined 24 years experience in our field.

George Heath, of Los Angeles is our Western manager, while Al Harrison has the Southern region out of Houston.

Phil Sprague Jr.
President

THE HAYS CORPORATION • MICHIGAN CITY 8, INDIANA

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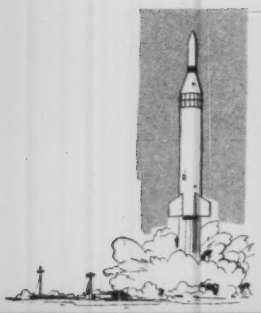
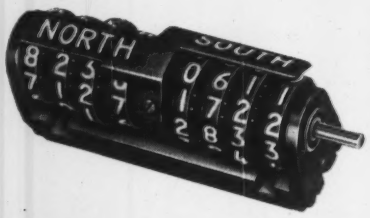


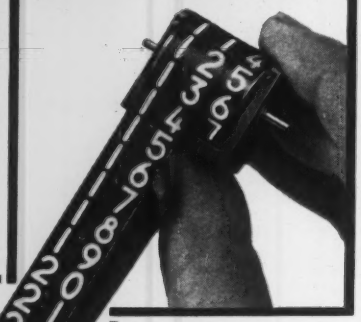


Precision Readout Counters for navigational and control systems include Tandem counters (left), concentric drums, and multi-bank types. "Application Engineered" as complete packages.

PRECISION readout (DIGITAL IN-LINE) COUNTERS

High Speed Counter works at 1000 rpm with low torque and miniature size. For aircraft fuel-flow meter and similar applications.

New Concepts in Fast, Accurate Data Presentation



Precision Counter has completely internal supporting structure for instrument applications requiring extreme compactness, light weight and ruggedness. Three or five wheels, numerals in enamels or fluorescent paints.

New 360° Tape-Type Bearing Counter recently developed for digital readout of angular relationship. Tape greatly reduces size and weight over conventional devices. "Application Engineered" as required.

Now you can use modern digital readout whenever extreme accuracy and precision indication are required. Veeder-Root Instrument-type Counters have "Application Engineered" tolerances, meet severe environmental specifications, operate accurately at high speeds, and offer wide selections of gearing and package designs.

Here are just a few of the ways Veeder-Root Precision Readout can improve and simplify product operation and performance . . .

- Figures and letters are positive, and easily comprehended
- In-line presentation more *quickly* read
- Replaces micrometer and vernier devices
- Maximum readability in miniature sizes
- Fractions, degrees are positively displayed

Take full advantage of digital readout with Veeder-Root Precision Counters — for military, aircraft, missile and industrial instrumentation. Standard types and special designs for all types of application, and design assistance is available from Veeder-Root Counting Engineers. Write or call.

High speed miniature counter suitable for applications requiring small size and weight, low torque and low cost. Internal pinion, ½" wheels, ⅛" characters.

Veeder-Root

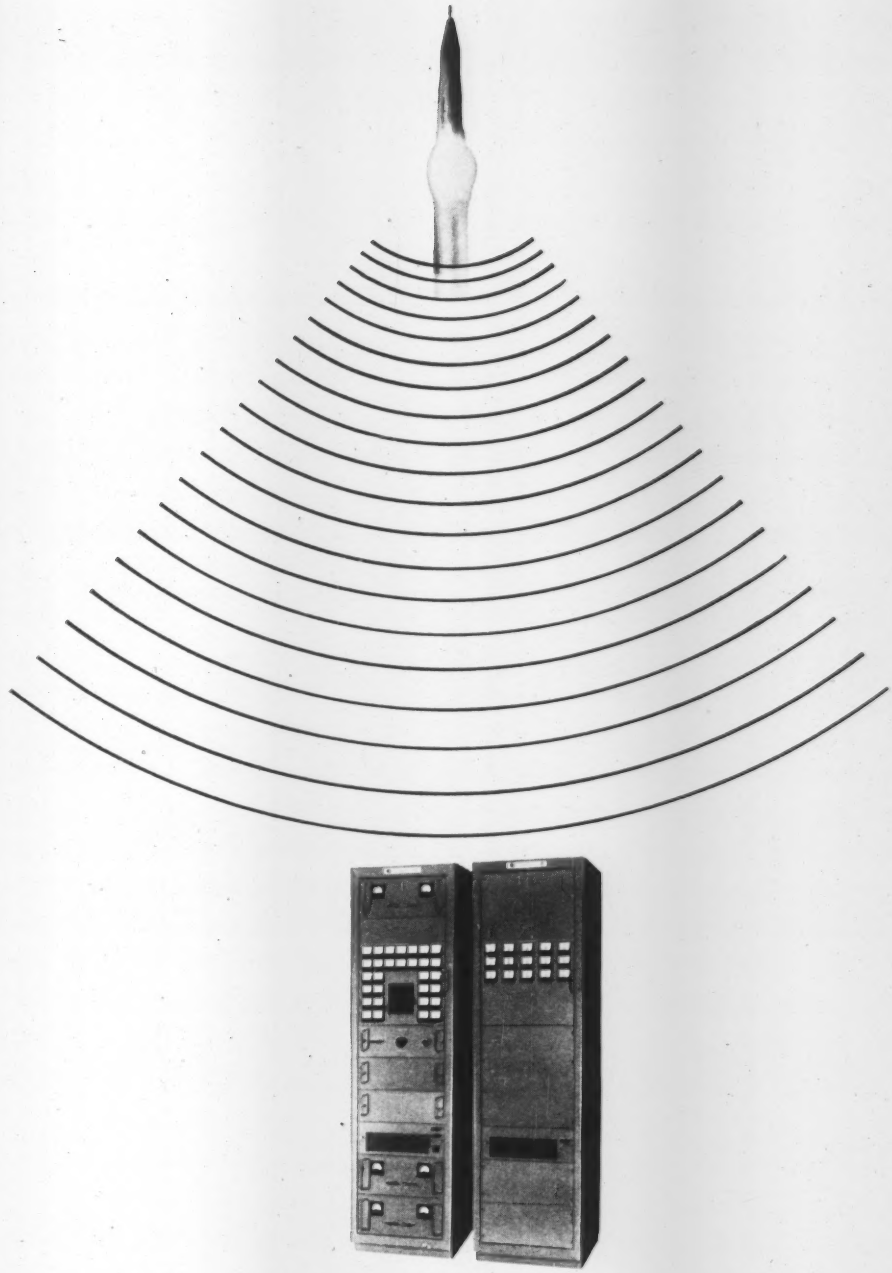
HARTFORD 2, CONNECTICUT

"The Name that Counts"

New York • Chicago
Los Angeles • San Francisco
Seattle • St. Louis
Greenville, S. C. • Altoona, Pa.
Montreal
Offices and Agents in other principal cities

VR9-88

CIRCLE 9 ON READER-SERVICE CARD

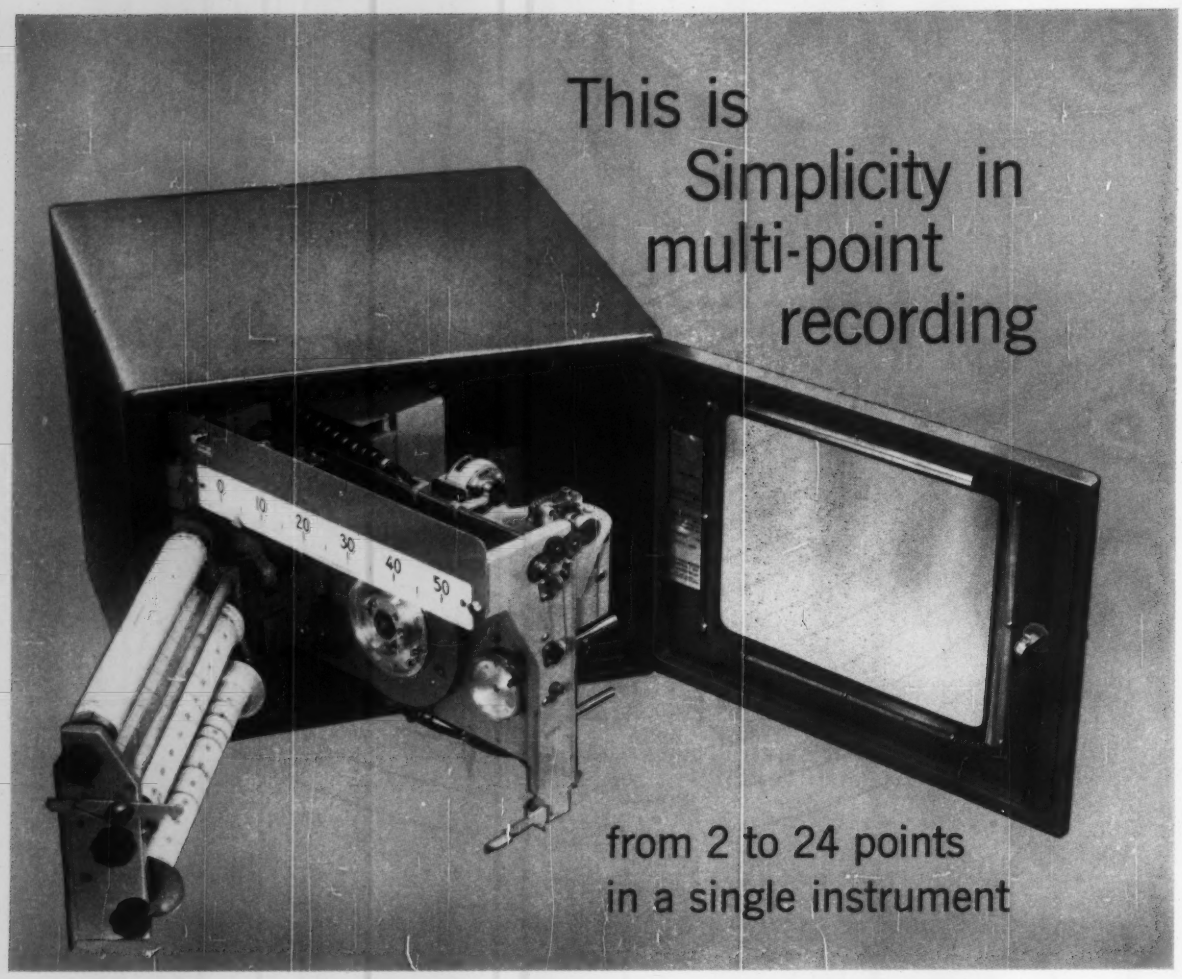


NEW FROM TELECOMPUTING...A Flexible PAM/PDM Automatic Decommutation System–This new system will decommutate up to 90 channels of IRIG telemetry data simultaneously with a system error of not more than ±0.3 percent of full scale at repetition rates of 75, 90, 150, 180, 300, 450, 600, and 900 pulses per second. The system's modular translators, or output gates, are interchangeable and may be removed without affecting operation of the remaining units. Commutator speed changes as great as ±20 percent will not degrade system synchronization. An AMP patchboard receptacle permits crosspatching any translator to as much as 5 channels or a single channel to as many as 5 translators. Output for each decommutated channel is ±15 volts full scale analog or transducer output. For additional engineering and application information, write, wire or phone to

DATA INSTRUMENTS
DIVISION OF TELECOMPUTING
CORPORATION

12838 Saticoy St., North Hollywood, California • TRiangle 7-8181

CIRCLE 10 ON READER-SERVICE CARD



Simplicity is the keynote in the new Daystrom-Weston Model 6702 multi-point recorder – simplicity in both design and performance.

Open the door and you see the advantages of the Daystrom-Weston famous *unitized design* – no jungle of wires, no hard-to-get-at areas . . . every component related in the simplest, most serviceable, most efficient way.

Interchangeability is easier than ever – from one number of points to another . . . one range to another . . . one chart speed to another. You need only a change plug and *newly-combined* station indicator and printing wheel – two units instead of three.

The remarkable Daystrom-Weston D-PAK®, solid state Constant Current Source, eliminates batteries, standard cells, standardizing mechanisms . . . and their maintenance!

You also get all the advantages of the full Daystrom-Weston potentiometer line – long-term reliability . . . high resistance to shock and vibration . . . maximum flexibility (recorder-controller "packages", including panels and accessories, can be suited to your specific application).

You get all this, yet a single instrument handling from 2 to 24 points costs 15% less than the average multi-point! And it can readily be converted to a single-point, curve-drawing instrument by means of a pen accessory.

For further information, contact your local Weston representative . . . or write to Daystrom-Weston Sales Division, Newark 12, N. J. *In Canada: Daystrom Ltd., 840 Caledonia Rd., Toronto 19, Ont. Export: Daystrom Int'l., 100 Empire St., Newark 12, N. J.*

DAYSTROM-WESTON INDUSTRIAL INSTRUMENTS include a full line of recording and controlling potentiometers with strip and circular charts; mechanical recorders and indicators for pressure, temperature and flow; and non-indicating controllers, both electric and pneumatic.

DAYSTROM
WESTON
World leader in measurement and control

CIRCLE 11 ON READER-SERVICE CARD

utilizing the knowledge acquired by us in past experience. This computer solves the nozzle equation (or orifice equation) with an accuracy limited only by the sensing devices. Readout is provided in the form of an analog voltage and can be connected to a meter for static conditions or to a recorder for dynamic conditions. Response of the computer is limited only by the sensors.

Because the computer solves an equation which is normalized it can be used with any size orifice (nozzle) with equal resolution and response. Temperature compensation is provided to insure accuracy.

Lee F. Burns, Jr.
MBS Associates
Manchester, Tenn.

Editor, I&CS:

Referring to Inquiry A425: Enclosed is the Bristol Company Product Data P1220.3-2 which describes our new Low-Range IR Temperature Measuring Device. A minimum standard range of 0-200°F to a maximum standard range of 0-1100°F can be furnished. In addition, lower temperatures and suppressed ranges can be measured.

R. H. Kennedy
The Bristol Company
Waterbury, Connecticut

Editor, I&CS:

We were interested and impressed by your circulated correction, but somewhat surprised by an apparent omission. Because of the evident importance you attach to a properly printed publication, and because of your eminence in the control field, we would have expected, along with your correction, the details of your broken type detector circuit.

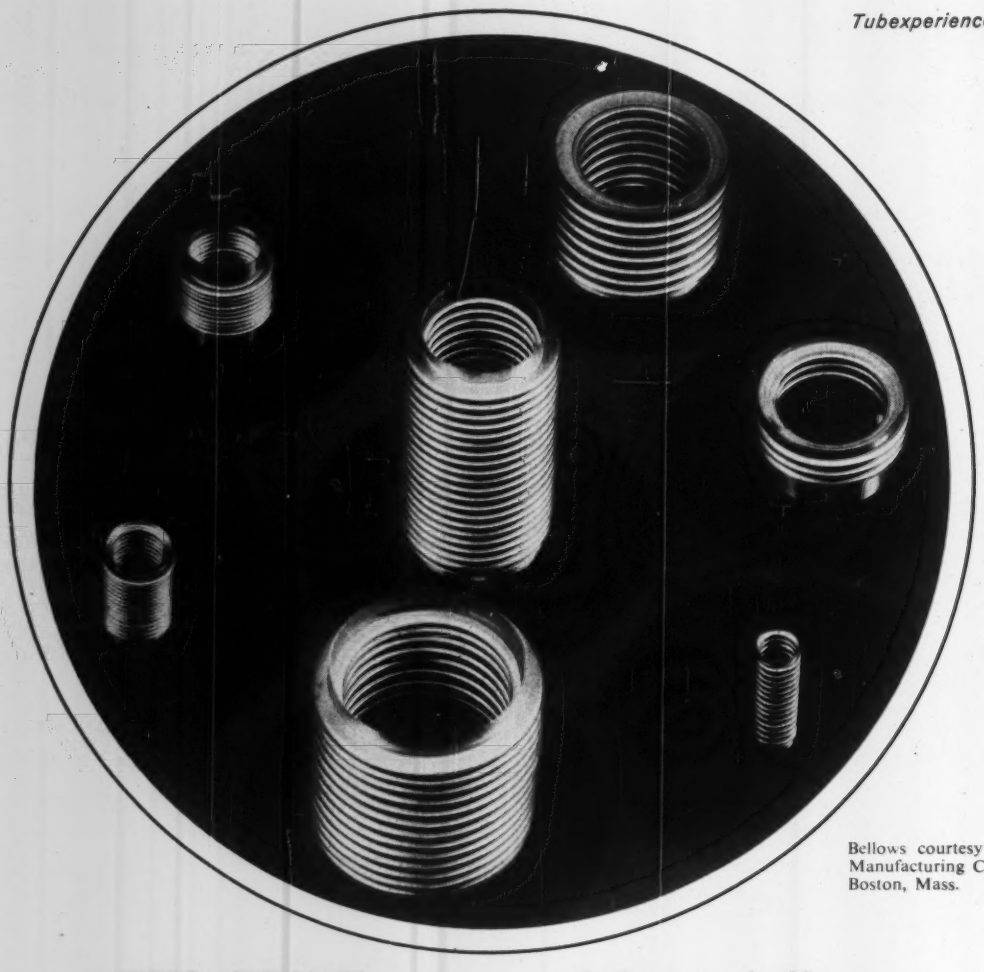
William E. Bates
Superior Controls, Inc.
Westfield, N. J.

In this case, the broken-type detector was an eye, unaided even by a reading glass. Obviously an electronic scanning device, scanning each page as it comes off the press, and operating at a speed sufficient to stop the press before the next page is printed, is called for.

At the present rate of technological development this item should be on the market before this letter reaches you. Meanwhile, we are reading page proof!

Statham
Deep in the heart of nearly every ballistic missile in the nation's space-age arsenal is the Statham transducer. Of more than 40,000 parts in a missile, none is more vital than its transducing elements. Without them, it would be difficult if not impossible to determine component reliability or to record the functional performance of the missile in space.
Typical of these rugged instruments is Statham's new 250-millivolt high output pressure transducer that permits direct connection or commutation to low level voltage-controlled oscillators. This ¼-volt series, designed for sophisticated instrumentation, is fully described in Data File ICS-909-1.
For leadership in measurement
STATHAM INSTRUMENTS, INC.
12401 W. Olympic Blvd.
Los Angeles 64, California

CIRCLE 12 ON READER-SERVICE CARD



Bellows courtesy Clifford Manufacturing Company, Boston, Mass.

750,000 flexures without failure

—a common performance record for bellows formed from Superior Thin-Wall Tubing

Bellows, more sensitive than spirals and better adapted to accurate measurement of pressure and vacuum, or absolute pressure in the low and intermediate range, must withstand thousands of flexures without failure. The tubing from which they are made must be highly uniform in physical and mechanical properties and must have the invariably smooth surfaces that contribute so much to good fatigue life. It must be extremely ductile—forming pressures run as high as 5000 psi. Brazing operations used to fasten it to another assembly may subject it to temperatures up to 1800°F. It must have excellent corrosion resistant characteristics. And it must be free of carburization, dents and pickups that lead to premature fatigue failure of the bellows in service.

Thin-wall tubing of this quality—usually under .010 in. max. wall thickness and held to a tolerance spread of only one-thousandth inch—requires the skills and facilities of tubing specialists. Superior maintains production standards fully in keeping, employs special handling procedures, uses special controlled-atmosphere furnaces to provide the uniformly annealed tubing demanded. Superior tubing is produced in a wide range of analyses, in both Seamless and WELDRAWN® types, and to specified IDs, ODs and wall thicknesses.

Bellows tubing is just one of many types supplied by Superior. Available are more than 120 analyses, in a wide range of sizes, and meeting almost any requirement. For a good glimpse of the field covered by Superior, send for Bulletin 41. Superior Tube Company, 1968 Germantown Ave., Norristown, Pa.

Superior Tube

The big name in small tubing

NORRISTOWN, PA.

All analyses .010 in. to 5/8 in. OD—certain analyses in light walls up to 2½ in. OD

West Coast: Pacific Tube Company, Los Angeles, California • FIRST STEEL TUBE MILL IN THE WEST

CIRCLE 13 ON READER-SERVICE CARD

Editor, I&CS:

In answer to Reader Inquiry A424, Mr. Charles Peterson, 43 Edgerton Ave., Rochester, N. Y. has built, and I believe still has plans and specifications for, a device such as you mention.

Herman Venes
General Electric Co.
Syracuse, N. Y.

reader inquiries

Electromagnet

Manufacturer's representative in Belgium requests quotations on electromagnet to subject solutions in test tubes to a magnetic field. Specifications: 10,000 to 15,000 gauss; space between poles 4 x 4 x 4 cm or 5 x 5 x 5 cm; field homogeneous to thousandths. A-439

Pedometer

Research associate at university human performance lab is interested in obtaining a pedometer that records steps taken by subjects. A-440

Temperature in Cooker

Manufacturing company seeks means of measuring temperature inside steam-jacketed cooker. Load contains chunks of material which would break bulb. Flush mounted thermo elements tend to pick up wall temperature. A-441

Dc to 4000 cps Tape Recorder

University pharmacology department head needs tape recorder which can record on 6 or 8 channels with flat characteristics from dc to 4000 cps. A-442

Repair Manual for Filled Thermometers

Thermometer manufacturer seeks manual for repair of filled thermometers. A-443

Company Identification

Plaster mill engineer would like to get address of "Mark N Laboratory," manufacturer of a thickness gage. A-444

Trade Name and Company Address

Purchasing agent of lab seeks manufacturer of "Physiograph," an electronic physiological recording instrument. Also, present address of Brociner-Mass Instruments Co., formerly of 1546 Second Ave., New York 28, N. Y. A-445

Sonar Fish Finder

Plant superintendent seeks sonar transducer in 200-to-300-kc range for home gadgeteering. A-446

the world's most expensive inch of recording tape

There's no question about it—if there were a dropout in this inch of tape it could cost you plenty. That's why our customers invariably demand perfection from our EP Audiotape —the *extra precision* magnetic recording tape for computers, automation, telemetry and seismography.

Audio Devices' battery of Automatic Certifiers is one of the unique means used to make sure EP Audiotape always meets customers specifications. The Automatic Certifier records and plays back every inch of the EP Audiotape under test. These tests can be so demanding that if the tape fails to reproduce just *one* test pulse out of the 40 million put on a single reel, the entire reel is rejected. There are no *if's, and's,* or *but's.*

This is just one of many special quality-control operations. From raw material to hermetically sealed containers, every reel of EP Audiotape gets individual attention.

For more information write for free Bulletin T112A. Write Dept. TI, Audio Devices, Inc., 444 Madison Avenue, New York 22, N. Y.

TYPE EP audiotape TRADE MARK

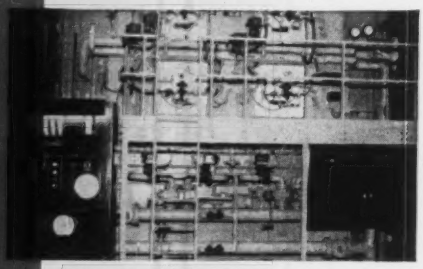
AUDIO DEVICES, INC.
444 Madison Ave., N. Y. 22, N. Y.
In Hollywood: 840 N. Fairfax Ave.
In Chicago: 5428 Milwaukee Ave.
Export Dept.: 13 East 40th St., N. Y., 16
Rectifier Division: 620 E. Dyer Rd., Santa Ana, Calif.

CIRCLE 14 ON READER-SERVICE CARD

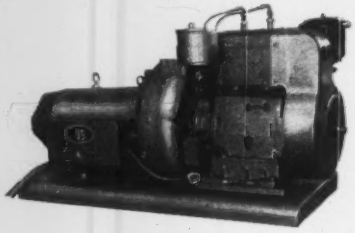
DOUGLAS AIRCRAFT

TULSA DIVISION

eliminates the risk of flame-outs caused by power outages with . . .



MICRO-POWER



In plants like Douglas Aircraft Company, Inc., in Tulsa, Oklahoma, where a continual supply of steam is vital to production processes, every precaution must be taken to assure against the hazards of boiler flame-out. To safely regulate the shutting down of its burners in the event of flame-out, the company utilizes highly sensitive electric controls. Since these flame failure controls *are* electric and must depend on a constant, unwavering power supply for successful operation, a further precaution is taken . . . MICRO-POWER.

At Douglas Aircraft in Tulsa, Micro-Power serves as the dependable rear guard to the boiler room. It provides a constant source of steady, independent electrical power as required by the safety controls, thereby eliminating voltage fluctuations and protecting against power failure.

MICRO-POWER IS ALSO USED . . .

- on microwave installations for communications, for remote control, for telemetering.
- for refinery and chemical process indication and control.
- by public utilities for protective relaying, telemetering and load distribution.

MICRO-POWER PROVIDES . . .

- a constant source of electric power.
- voltage and frequency at usable value during transfer from motor to engine.
- stable voltage output.
- flywheel starting — no storage batteries.
- electrical isolation from commercial source — no voltage dips or peaks to affect microwave equipment — no transfer switch.
- return to motor drive after commercial power restoration without interruption of voltage.

The Douglas Aircraft Company, Inc., Tulsa Division, "Micro-Power" application is just one of a wide range of uses for this versatile standby power unit. For complete product and application information, call or write . . .

UNITED STATES MOTORS CORPORATION — MICRO US POWER — OSHKOSH • WISCONSIN

UNITED STATES MOTORS CORPORATION

102 West Fifth Avenue

OSHKOSH, WISCONSIN

CIRCLE 15 ON READER-SERVICE CARD

events

January 11-13

Sixth National Symposium on Reliability and Quality Control, Statler Hilton Hotel, Washington, D. C. For information write Bod Haid, Reliability Engineering Div., Battelle Memorial Institute, Columbus, Ohio

January 25-29

Stress Measurement Symposium, on campus of Arizona State University, For information write Strain Gage Readings, 5602 East Monte Rosa, Phoenix, Arizona.

January 26-27

Society of Vacuum Coaters Technical Conference, New York City, N. Y. For information write John Scharnberg, Bee Chemical Co., 1233 S. Stony Island Ave., Chicago 33, Ill.

January 30-February 3

Committee Week for the American Society for Testing Materials, Netherland Hilton Hotel, Cincinnati, Ohio. For information write Fred F. Van Atta, Asst. Sec., A.S.T.M., 1916 Race St., Phila. 3, Pa.

April 6-8

Institute of Environmental Sciences National Meeting, Biltmore Hotel, Los Angeles. For information write Bruno Forscher, 16446 Bircher St., Granada Hills, Calif.

April 19-21

Polytechnic Institute of Brooklyn's Tenth International Symposia, Engineering Societies Bldg., 33 West 39th St., New York City. For information write Jerome Fox, Polytechnic Institute of Brooklyn, 55 Johnson St., Brooklyn 1, N.Y.

March 16-18

Twenty-Third Annual Short Course for Superintendents and Operators of Water and Sewage Systems, will be held on campus of Louisiana State University. For information write Fred H. Fenn, College of Engineering, Louisiana State University, University Station, Baton Rouge 3, Louisiana

April 20-22

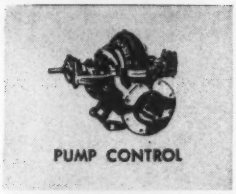
Texas A & M Symposium on Instrumentation for the Process Industries, will be held on campus of Texas A & M. For information write N. E. Welch, Chemical Engineering Dept., Agricultural and Mechanical College of Texas, College Station, Texas

May 3-5

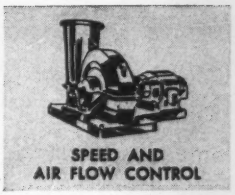
1960 Western Joint Computer Conference, Jack Tar Hotel, San Francisco, Calif. For information write H. M. Zeidler, Stanford Research Institute, Menlo Park, Calif.

May 9-11

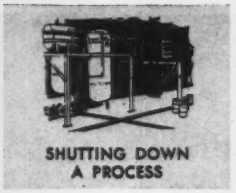
Annual PGMTT Symposium, sponsored by IRE Professional Group on Microwave Theory and Techniques, Hotel del Coronado, Coronado, Calif. For information write David B. Medved, CONVAIR, Division of General Dynamics, Mail Zone 6-172, Box 1950, San Diego 12, Calif.



PUMP CONTROL

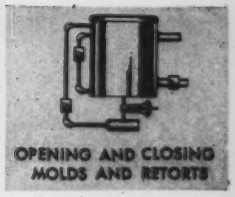


SPEED AND AIR FLOW CONTROL



SHUTTING DOWN A PROCESS

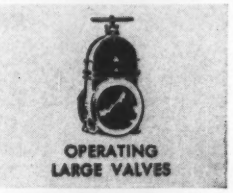
OPERATING HYDRAULIC VALVE



OPENING AND CLOSING MOLDS AND RETORTS

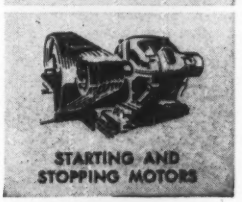
Bristol C1C500 Time-Cycle Controller features accurate, reliable process timing

PISTON OPERATOR



OPERATING LARGE VALVES

DAMPER REGULATION



STARTING AND STOPPING MOTORS

improved automatic process time-cycle controller

. . . the key to process automation

Plant processes that depend on the timing of such operations as those graphically represented here and many others can be put under exact control with Bristol Process Time-Cycle Controllers.

Bristol Automatic Time-Cycle Controllers are the result of over forty-five years of pioneering research and development in timing industrial process operations. Thousands of these controllers have been built for use in manufacturing a wide variety of products, such as rubber goods, molded plastics, dry ice, tires, coffee, tobacco, chemical products, rayon, dyeing of woolen goods, and many others.

The Model C1C500 Cycle Controller operates on the same basic principle as that used in previous models. However, the improved model has a number of *design refinements* that *simplify it* and make it *more flexible to apply* and *more convenient to use.*

Number of Operations That Can Be Timed: Up to ten process-variables can be controlled by either pneumatic pilot valves or electric pilot switches. Each valve or switch can be operated up to 24 times during a complete cycle. Timing cam easily adjustable. This feature gives increased versatility and broadens the controller's application in the processing industry.

PILOT VALVES OR PILOT SWITCHES: Pneumatic and electric pilots are easily interchangeable by the user—great versatility of application.

Pneumatic Pilots are high-capacity valves.

Electric Pilots—single-pole and double-pole double-throw switches offered—15 amp capacity.

TIMING DISCS are of heavier and improved design for precision timing and ease of setting up a time schedule or changing an existing one. Ranges of from 0 to 15 minutes to 0 to 360 minutes are available.

THREE ADDITIONAL AUXILIARY SWITCHES available for operating only once during a cycle.

If you have operations in your plant that must be carried out according to a definite and accurate time schedule, we invite you to investigate this valuable control instrument. Our engineers have had long experience in the application of Automatic Process-Timing Controls in practically every industry. They're ready to work on your problem now. Write today for our Bulletin C305. The Bristol Company, 113 Bristol Road, Waterbury 20, Connecticut. o.7

BRISTOL... for improved production through measurement and control

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

CIRCLE 16 ON READER-SERVICE CARD

DEKORON
PROTECTO-PAC

Advantages of Dekoron all-plastic instrument tubing harness are *now four-dimensional.* You get, in addition to its inherent lower-cost installation . . . chemical . . . impact . . . fire resistance.

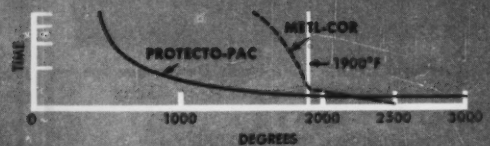
And the advantages of Dekoron Protecto-Pac multiply the closer you examine them. For example, you can get Protecto-Pac in many forms to suit your requirements exactly — *from stock.*

If there is danger from weld splatter, sparks or a potential fire hazard — order Dekoron Protecto-Pac Type FB. If you wish to bury it underground — specify low-cost Protecto-Pac Type B. Both types supplied with virtually any number of individual tubes, and also with *new metal armor protection.*

You can pay more but you can't buy better, longer-lasting instrument line harness than *Dekoron — America's Premier Instrument Tubing Line.*

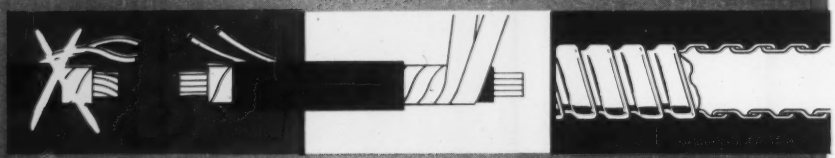
AA-0189

TYPE FB
FOR FIRE AND IMPACT RESISTANCE



FIRE RESISTANCE of copper tube bundles is superior up to 1900°F, less pronounced from 1900° to 2500°F. Above 2500° Protecto-Pac Type FB is superior to copper tube bundle.

TYPE B
FOR UNDERGROUND BURIAL



NO "CORKSCREW" effect, as with twisted tubes, because tubes lie straight in bundle to give faster, neater individual tube take-offs.

NEW IMPROVED INSULATION is composed of two wraps of asbestos tape bonded to backing of Mylar® for maximum protection.

DEKORON PROTECTO-PAC Type FB or Type B can be supplied with 24 gauge galvanized steel armor of modified square-lock construction with cord packing for maximum strength and flexibility.

Dekoron® products QUALITY • RESEARCH • SERVICE

SAMUEL MOORE & COMPANY • DEKORON PRODUCTS DIVISION • MANTUA, OHIO

CIRCLE 17 ON READER-SERVICE CARD

trends

Magnetic amplifier market was about $100 million in 1957, $125 million in 1958, will be $150 million in 1959, says H. Goldsmith of Magnetic Amplifiers, Inc. About 60% is military.

Nuclear instrument sales in 1959 will reach $50 million, says A. Edelman of Business & Defense Services Administration, Dept. of Commerce. This includes detectors, reactor controls, and process instruments using radioactivity technique, such as isotopes.

Natural-gas utility and pipeline industry now has assets of $22 billion, more than double of what it was ten years ago; has moved from sixth to fifth place among US industries. The industry will spend about $30 billion in next decade, going from $1.86 billion in 1959 to $4.3 billion in 1970, says Public Utility Fortnightly.

Computer census in Sept-Oct Punched-Card Data Processing shows 383 large-scale digital computer systems, including 115 IBM 705; 444 medium-scale digital computer systems, including 190 IBM 650 with tapes; 1691 small-scale digital computers, including 730 IBM 650 with cards; and 5636 miscellaneous computers, including 4000 IBM 604.

Export Services Branch of British Board of Trade reports that under 5-year trade agreement with Russia, a total of 4 to 4.5 billion rubles of equipment will be exported to Russia. This includes control and measuring instruments and radio and TV equipment exports in the amount of 90-100 million rubles. Control valves will be 40-50 million rubles. Much plant equipment also will have its instrumentation included.

Today, USA has less than 50,000 people trained in the technologies of instrumentation and automatic control. In the next decade, 3 million will be needed, says A. G. Hathaway of United Electronics Laboratories. In automated plants, one employee out of every 100 is an instrumentation technician; the average in all manufacturing industries is only 1.4 per 1000 employees. We need to increase ratio of technicians to engineers from present one-to-one, to five-to-one.

US electronics production in 1959 will be $8.5 billion, says BDSA.

Electronic data processing market is above $1 billion, says R. E. Lewis, Pres., Sylvania Electric, and should be $2 billion by 1965.

Electronic data processing market is $1.5 billion, says W. Stevenson of IBM, and should be $4 billion in 1965.

In 1958, US engineering colleges granted 35,322 Bachelor's degrees, 5788 Master's degrees, 647 Doctorates. Electrical engineering led the field with 27.1% of Bachelors, 27.4% of the Masters, and 22.3% of the Doctorates. Mechanical engineering was second with 25.6%, 16.7% and 11.8% respectively. Civil engineering was third with 14.5%, 14.2% and 10.2% respectively.

news

Computer Aids Chemical Research

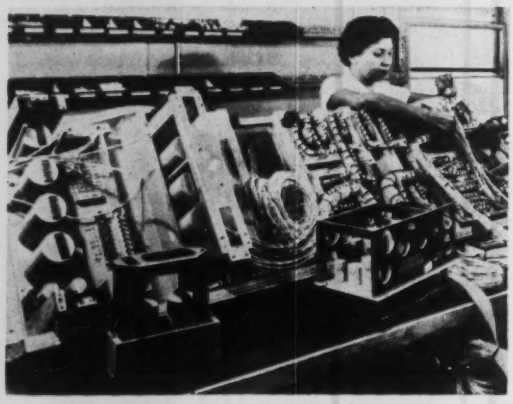
DETROIT, MICH.—The Dow Chemical Co., fourth largest U.S. chemical concern, now has a Burroughs 220 electronic computer at work to speed up its research in rocket fuels, textile fibres, plastics, and other chemical

products. Said to be the first computer of its type in the chemical industry, it is capable of performing 8000 logical instructions per second. A 5000-word magnetic-core memory, paper tape input-output and two magnetic tape units round out the equipment. Details are available from Burroughs Corp., 6071 Second Ave., Detroit 2, Mich.

CIRCLE 150 ON READER-SERVICE CARD

Mockups Speed Production

GLENDALE, CALIF.—Librascope is using wooden "mockups" extensively to reduce the lag between design and actual production of computer and data processing

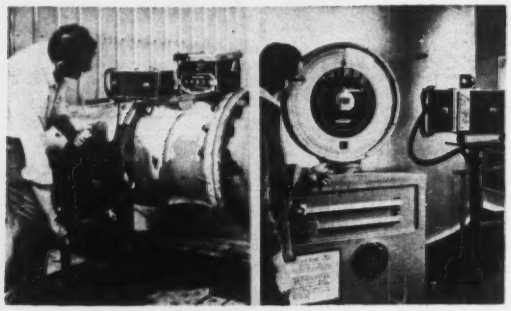


systems. While the engineering department is working on the system design the industrial engineers can thus plan the mounting, casting, and production tooling necessary for assembly of the equipment. Librascope is a subsidiary of General Precision Equipment Corp., located at 808 Western Ave., Glendale 1, Calif.

CIRCLE 151 ON READER-SERVICE CARD

Meter Calibration By Photography

MURRAYSVILLE, PA.—This shows the heart of the special test facility constructed by the Rockwell Manufacturing Company's Meter and Valve Division at Murraysville, Pa., for testing its high-capacity Turbo-Meter. The division's engineers are using two Polaroid Land

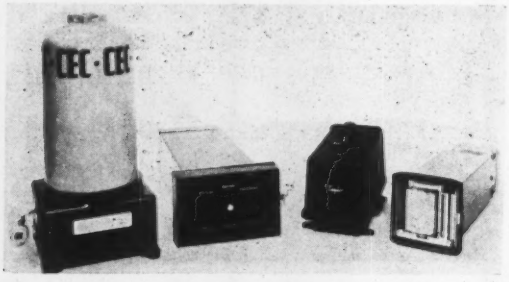


Cameras connected by a pneumatic air hose to record the test data, enabling them to cut man-hours and get more accurate readings. At left, mechanical research engineer Richard L. Crumley is shown standing beside the prototype Turbo-Meter (which was installed in a standard 16-inch piping system) as he pushes down a bicycle pump handle to simultaneously trigger the two Land Cameras —one facing the meter's register head and the other facing a specially-built weigh scale. The two readings, taken at the same instant, are equated to the barrels/hour performance curve for the flowmeter. The facility uses a 47,000-gallon storage and weigh tank, a 350,000-lb weigh scale accurate to ±0.007%, 16″ piping, and equipment for 15,000 bph flow. Details are available from Polaroid Corp., 730 Main St., Cambridge 39, Mass.

CIRCLE 152 ON READER-SERVICE CARD

Chromatograph-Pneumatic Combination

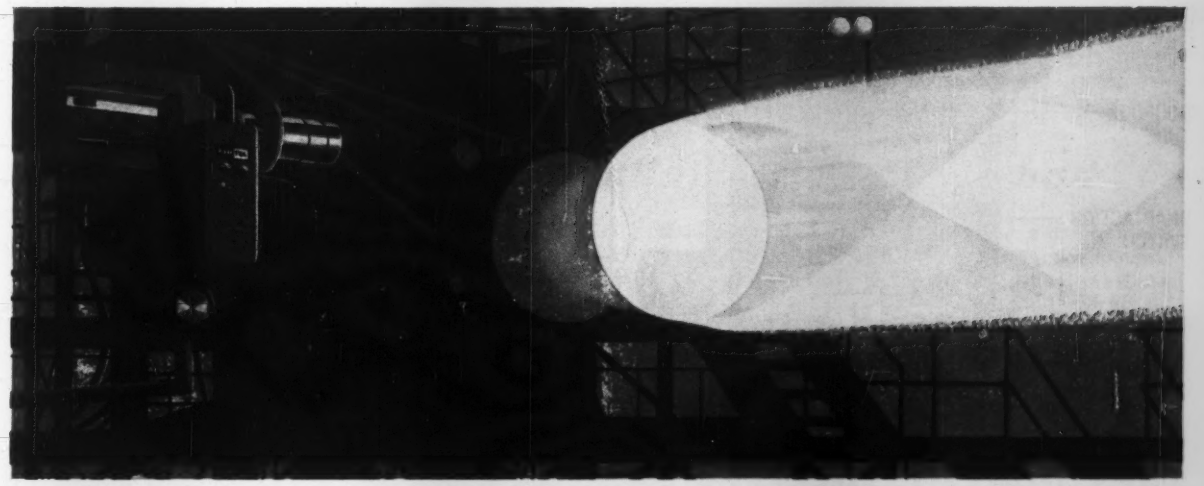
PASADENA, CALIF.—Previously, the application of the flexible and comparatively low-cost chromatograph as the primary element for continuous process control was limited to monitoring because it is a batch-type instru-

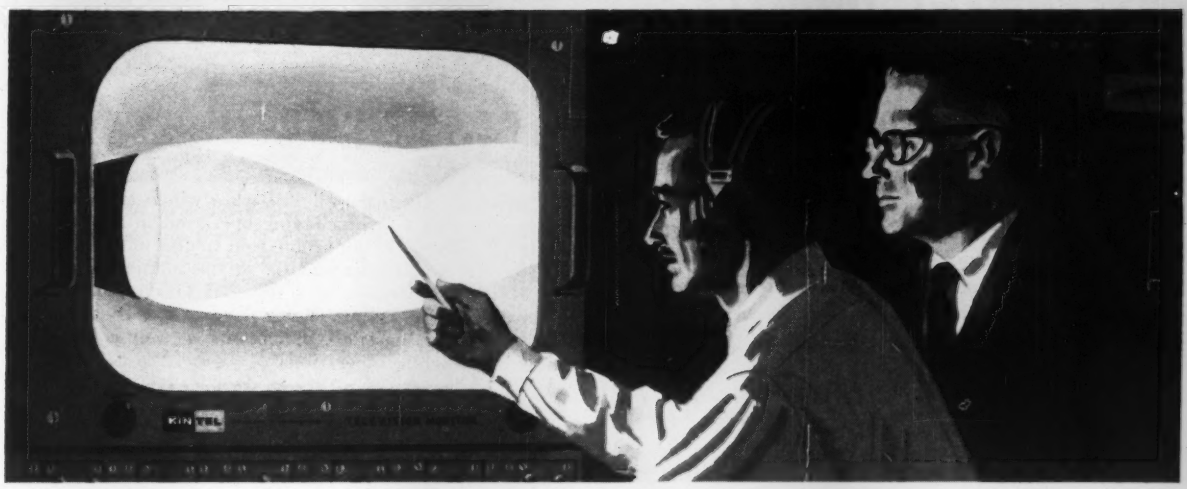


ment. However, a pneumatic control especially modified for the application, after a development program by Consolidated Electrodynamics stores "peak" values from the standard CEC Type 26-202 Process Chromatograph and uses these values as the basis for process control until the next peak value is supplied by the chromatograph. Details can be obtained from Consolidated Electrodynamics Corp., 360 Sierra Madre Villa, Pasadena, Calif.

CIRCLE 153 ON READER-SERVICE CARD

To see where man cannot survive...





Convair–and hundreds of other firms–use KIN TEL Closed Circuit TV

CONVAIR, NORTHROP, LOCKHEED, DOUGLAS and virtually all other major missile and aircraft manufacturers use KIN TEL closed circuit TV to observe operations that are tedious, difficult, or even impossible for men to watch.

Other industries, too, rely on KIN TEL TV to perform a countless number of jobs safely, inexpensively, tirelessly. U. S. STEEL uses it to see inside open-hearth furnaces. WESTINGHOUSE watches nuclear power-reactor tests with it. AMERICAN POTASH AND CHEMICAL uses it to monitor production-line and warehousing operations. All told, hundreds of companies – both large and small – have found profitable uses for this equipment.

KIN TEL's basic TV system, consisting of camera, camera control, and receiver, is surprisingly low in cost, and may be obtained on a lease-purchase plan. The camera is rugged, compact. Picture quality is almost twice that of the best home TV reception. A complete line of housings and accessories permits observation of nearly every kind of operation, in all kinds of environments.

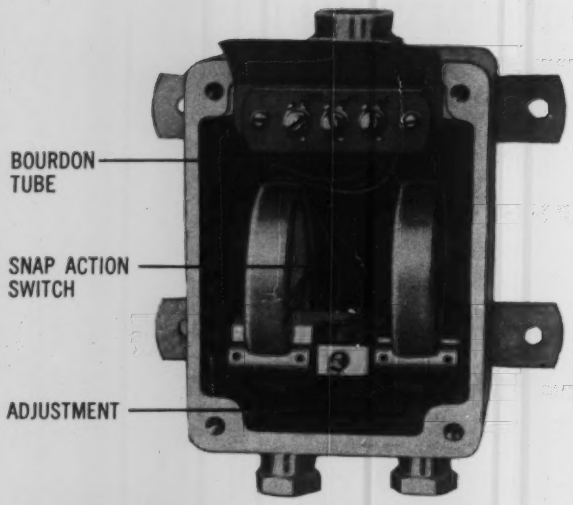
Nationwide factory-trained engineering representatives can show you how KIN TEL TV can be put to profitable use in your company. Write direct for TV catalog 6-103 and the name of your nearest representative.

5725 Kearny Villa Road
San Diego 11, California
BRowning 7-6700

KIN TEL
A DIVISION OF
COHU
ELECTRONICS, INC.

KIN TEL–pioneer and leader in television systems for industry.

CIRCLE 18 ON READER-SERVICE CARD



INSTRUMENT QUALITY DIFFERENTIAL SWITCH

Senses pressure differences from 4 p.s.i. to 9000 p.s.i.

Proof Pressures ranging from 500 to 12,000 p.s.i.

A good illustration of this switch function is its application on multiple stage compressors. If a failure occurs in one of the stages the switch will signal the pressure difference change or shut down the system to prevent damage.

EXTREMELY ACCURATE

Simplicity of direct acting design plus rugged precision construction make for long, unchanging repeat accuracy.

Note, that we don't use

LINKAGES AND BEARINGS which, as they wear, cause settings to drift.

IN ANY POSITION

on moving equipment, even under vibration, switch performs with equal efficiency.

Because we don't use

LIQUID SWITCH ELEMENTS which require that the pressure switch be mounted absolutely vertical, which make it critical to vibration.

ASK FOR NEW CATALOG 9-PS FREE

PRESSURE SWITCH DIVISION

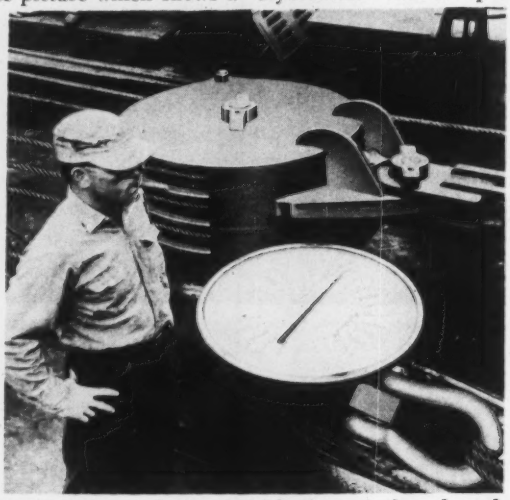
barksdale valves

5125 ALCOA AVENUE • LOS ANGELES 58 • CALIFORNIA

CIRCLE 19 ON READER-SERVICE CARD

Hydraulic-Scale Dynamometer

DETROIT, MICH.—Engineers in need of ruggedly built dynamometers have long been using hydraulic scales for heavy weight and tension measurements. A good example of such an application is demonstrated by the picture which shows a "Hydroscale" with a capacity



of 100,000 lb attached to hold back a winch and used as a dynamometer on a pipe-laying operation in the Pacific Ocean. It played an important role in the pulling of an outfall 7 miles into the Pacific in the matter of just 7 days. Hydroway Scales, Inc., Box 531 Oakridge Station, Royal Oak, Mich., manufactures "Hydroway" Dynamometers for these and similar applications, as well as hanging scales for weighing operations.

CIRCLE 154 ON READER-SERVICE CARD

ASA, the American Standard Association, announces a revised Standard for Measurement of Direct Interelectrode Capacitances (C60.6-1959); a second supplement to Methods of Measurement of Interference Output of Television Receivers (C16.25b-1959); and a new American Standard 16 mm Azimuth Test Film, Magnetic Type (PH22.114-1959).

REMINGTON-RAND's new Univac Larc Solid-State Computer can perform 250,000 additions or subtractions

of 12-digit decimal numbers per second, which is "200-times faster than anything in existence today."

CIRCLE 155 ON READER-SERVICE CARD

ELECTRONIC ASSOCIATES INC. again will hold specialized Application Courses early next year, one in January and one in March, 1960. The courses, of 2-week duration will consist of lectures and demonstrations, and will include an introduction to the analog computer, engineering math, and examinations of applications. Applications are to be addressed to Electronic Associates, Inc., Princeton Computation Center, P. O. Box 582, Princeton, N. J.

Simplify control problems...

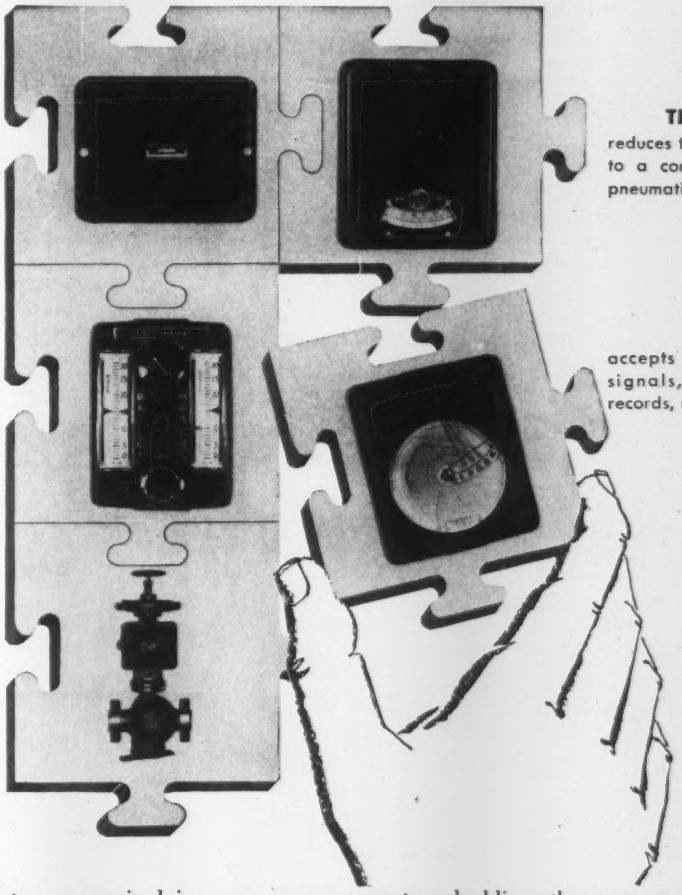
with the Bailey Building Block Method

Control problems are greatly simplified when you attack them using the Bailey Building Block Method. In a nutshell, the method consists of using standard components that fit together like building blocks. Virtually any control requirement can be handled by selecting standard components. Here are the parts you use and the functions they perform.

CONTROL RELAY
takes signals from the transmitter and computes corrective action in terms of pneumatic signals.

SELECTOR STATION
gives operator choice of hand or automatic control including set-point or bias adjustments.

POWER UNIT
is the "muscle" of the system. It performs whatever precise mechanical action is necessary to achieve control.



TRANSMITTER
reduces the measured variable to a common denominator, a pneumatic or electric signal.

RECEIVER
accepts pneumatic or electric signals, indicates and/or records, measurements.

Not all these components are required in every control system. You buy only what *your* system needs. When you change processes or add more automatic control, you can add additional standard components. Sometimes you may want to build a whole new system, re-using some of the existing components and adding other new ones. Spare parts inventory and maintenance training are reduced.

Hear the complete story of the Bailey Building Block System. Find how it can solve your control problems. See your Bailey Engineer or write for more information. G44-1

BAILEY METER COMPANY
1041 IVANHOE ROAD, CLEVELAND 10, OHIO
In Canada—Bailey Meter Company Limited, Montreal

BAILEY BUILDING BLOCK METHOD

RESULTS IN: FLEXIBILITY, SIMPLICITY, ECONOMY

BAILEY METERS

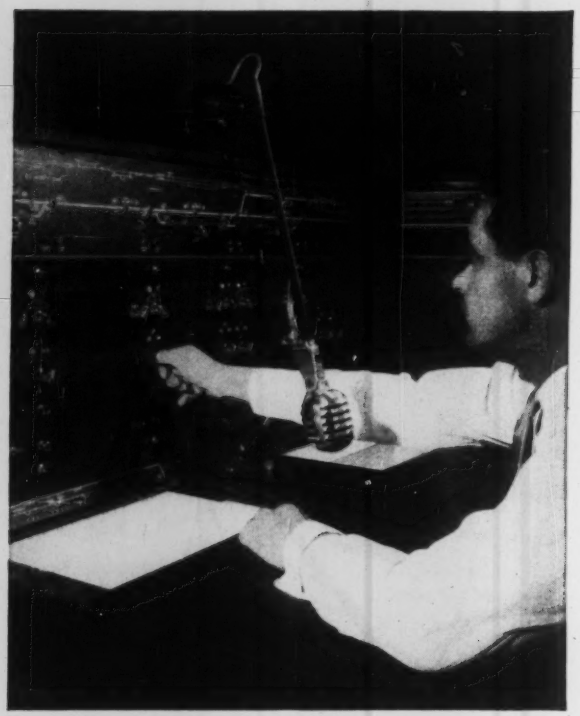
CIRCLE 20 ON READER-SERVICE CARD

BRISTOL special charts for railway traffic control

Using control equipment developed by Union Switch and Signal Division of Westinghouse Air Brake Company, Swissvale, Pa., one railroad dispatcher can direct the movement of trains over hundreds of miles of track.

One key feature of this streamlined dispatching equipment is the Union Automatic Train Recorder that indicates—on a custom-printed Bristol chart that you can see in the dispatcher's desk top above—the times that trains pass up to 57 specified locations.

The Bristol special chart used here is one of hundreds of special charts engineered and printed to instrument manufacturers' special requirements.



Do You Have a Chart Design Problem?

Backed by well over 60 years of chart-printing experience, The Bristol Company is the only instrument manufacturer with facilities to print charts for other instrument makers. The entire Bristol chart engineering service is at your disposal to assist you to design the best possible chart into your system.

Bristol can furnish you with charts for ink, electrical, heat, pressure, or light-beam recording.

Write for Bulletin Y1906 for complete details on Bristol's extensive chart-engineering facilities. The Bristol Company, 154 Bristol Road, Waterbury 20, Connecticut. 9.2

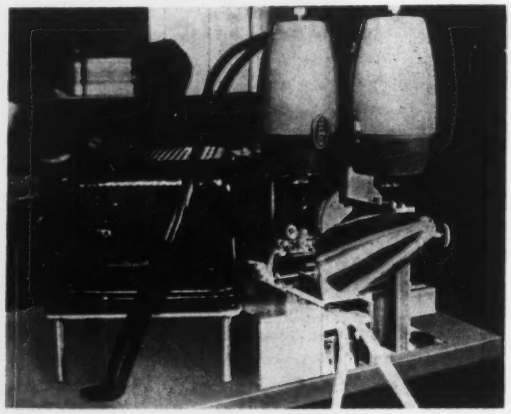
BRISTOL *TRAIL-BLAZERS IN PROCESS AUTOMATION*

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

CIRCLE 21 ON READER-SERVICE CARD

Automated Brokerage Service

PLEASANTVILLE, N. Y.—Ticker tape and TV have joined forces in the offices of Goodby & Co., 2 Broadway, New York, N. Y., to supply up-to-the-minute information



on the New York and the American stock exchanges, to partners, syndicate, and clients in the home office and 41 branches in 39 cities.

A ticker tape television system designed by General Precision Laboratory Inc., Pleasantville, N. Y. flashes pictures of the two tapes simultaneously on ITV screens. Two GPL cameras view the tapes; one camera is used for standby purposes.

CIRCLE 156 ON READER-SERVICE CARD

READ any surface temperature with Alnor® PYROCON

Equipment...material...metallic or non-metallic...flat, curved... revolving or stationary—you can read every surface temperature accurately in less than 3 seconds!

Compact, complete in precision design, this rugged instrument assures highest standards of speed, accuracy and dependability.

Alnor Portable Pyrocons come in scale ranges to 2000° F., with thermocouples for every application. You'll find full details on the Pyrocon exactly suited to your operations in Bulletin 4257. Send for your copy now. Write: Illinois Testing Laboratories, Inc., Room 518, 420 N. LaSalle St., Chicago 10, Ill.

Alnor PRECISION INSTRUMENTS FOR EVERY INDUSTRY

CIRCLE 22 ON READER-SERVICE CARD

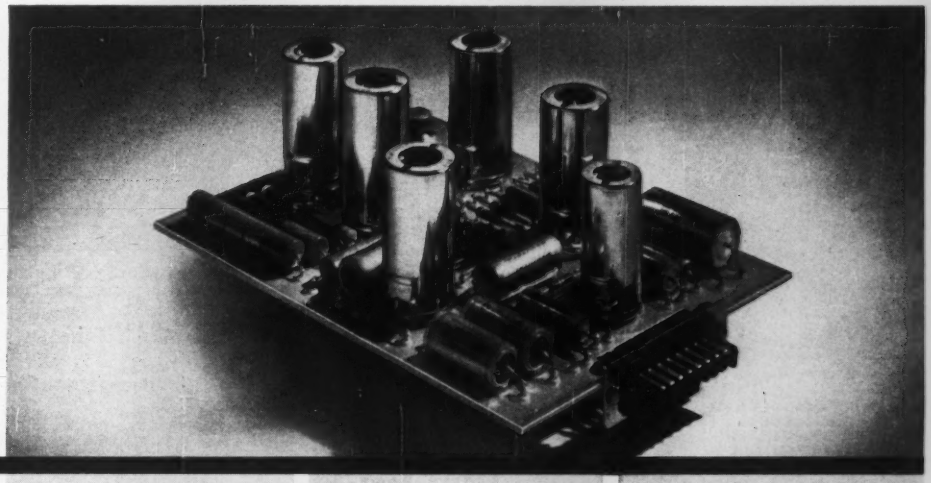
Philbrick introduces . . . . . OPERATIONAL AMPLIFIERS DESIGNED SPECIFICALLY FOR MILITARY APPLICATIONS

Philbrick now offers an array of dc operational amplifiers which use MIL-approved components. They are reliable and rugged to withstand all standard shock, vibration, and environmental conditions; they meet military requirements for land, sea, air, and space applications.

USA-4 JX At the present moment these units are the highest performance, coolest running operational amplifiers available in the world today, commercial or military. Drift, noise, grid current, gain, bandwidth, damping and like characteristics including predicted reliability are so much improved that this series is now also a "best buy" for critical commercial instruments. Featuring ±100 volt output, and a guaranteed minimum dc gain of 100,000,000, there are plug-in models designed for slide mounting and others using turret terminals for permanently wired-in installations. Price **$170**

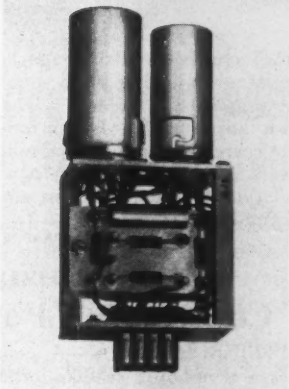
USA-4 series

- MIL-STD component parts.
- Reduced internal dissipation density
- Teflon-insulated stand-off terminals
- Machined aluminum plate with clear anodize finish
- Zero-adjust (balance) control is self contained and does not normally require readjustment
- Amplifier runs cool; tubes, resistors operate at a fraction of their wattage ratings, capacitors far below their voltage ratings

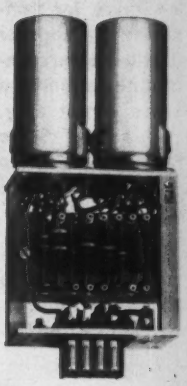


K2 series

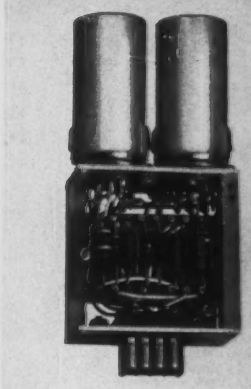
- Very low internal dissipation
- Differential inputs provided
- MIL-STD component parts
- Special open frame construction provides optimum free-air ventilation
- Epoxy glass terminal board
- Structural parts are machined aluminum with MIL-Irridite finish
- Amphenol Blue Ribbon type connector
- Provisions are made for secure mounting to the chassis



K2-PJ An accurate, low drift, low frequency chopper amplifier, the K2-PJ is ideally suited to stabilizing (servoing out the drift error in) an unstabilized dc amplifier such as the K2-WJ, K2-YJ, etc. When used as a preamplifier for the K2-WJ, the pair typically exhibits a long term drift of less than 100 microvolts, zero grid current, and a dc gain of 10 million. Write for details. Price (1 thru 99) **$85**



K2-WJ An efficient, fool-proof, high gain, low cost operational amplifier for all feedback manipulations. Its differential inputs allow use either as a "follower" or as a positive sign amplifier featuring "infinite impedance" input (open grid). The guaranteed minimum gain figure of 10,000 (over 15,000 typical), ±50 volt output, and the low drift make possible a wide variety of dc and low frequency operations such as summing, amplication, function generation, integration, differentiation, voltage clipping, tripping, flipping, flopping, and the like at accuracies substantially better than 1/10%. Price (1 thru 99) **$58**



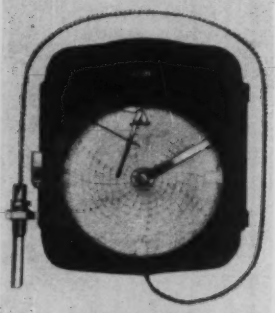
K2-YJ An operational amplifier identical in shape, size, and concept to the K2-WJ, but featuring twice the output voltage (±100v) and three times the output current (3 ma) at a sacrifice in gain. Most characteristics are also similar, including drift. Using the K2-PJ as a preamplifier for the K2-YJ, the pair becomes the coolest-running, most compact operational amplifier available which can provide ±100 volts output, chopper stabilized. Price (1 thru 99) **$62**

The analog way is the model way . . .
Write for more information on this addition to the Philbrick family of analog computors, components, and power supplies.

GEORGE A. **PHILBRICK** RESEARCHES, INC.
285 COLUMBUS AVENUE, BOSTON 16, MASSACHUSETTS

CIRCLE 23 ON READER-SERVICE CARD

FIG. D-32
MULTI-ANGLE
ADJUSTABLE
DIAL THERMOMETER



RECTANGULAR CASE
RECORDING
THERMOMETER
with Separable
Socket Connection

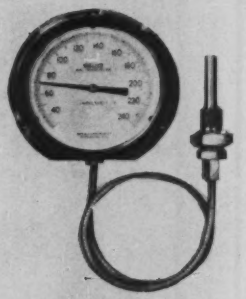


FIG. D-20
REMOTE
READING TYPE
DIAL THERMOMETER
with Separable
Socket Connection

Accuracy at every degree... that is what's built into MOELLER Dial Indicating and Recording Thermometers

Dependability has been the trademark of Moeller Instrument Co. for 91 years. Over that time it has been our pride to engineer and manufacture temperature indicating instruments of the highest quality and finest precision. Moeller Dial Indicating and Recording Thermometers have been specially designed for temperature sensitivity and for ruggedness under adverse installation conditions. Uniform scale divisions permit easy, accurate readings. Scale ranges from −40°F. to +1000° F. (or centigrade equivalent).

Complete details are available upon request — Mail the coupon for further information on these Moeller Instruments, today!

MOELLER INSTRUMENT COMPANY
SINCE 1867
132nd ST. and 89th AVE. • RICHMOND HILL 18, N. Y.
Representatives in Principal Cities

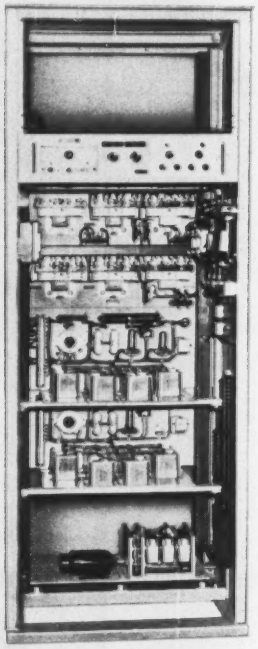
Gentlemen: Without obligation, please send me Moeller Catalog No. 150 on Dials Indicating and Recording Thermometers.

NAME .....
FIRM .....
ADDRESS .....
CITY ..... ZONE ..... STATE .....

CIRCLE 24 ON READER-SERVICE CARD

Automatic Gage Control in Hot Strip Mill

MILWAUKEE, WIS.—Automatic gage control from an x-ray gage signal, said to be the first such installation in the steel industry, is being employed on the five-stand finishing train of a midwestern hot strip mill. The equipment, furnished by Allis Chalmers Mfg. Co., Milwaukee 1,



Wis., includes two x-ray gages, magnetic-amplifier looper regulators adjusting stand speed, and digital positioning and proportional control for gage correction by screw-down adjustment. Also included is automatic tail-end gage correction by means of mill speed and selected screw recalibration. A production analyzer prints out gage deviation data, coil number, etc., employing digital positioning encoder devices.

CIRCLE 157 ON READER-SERVICE CARD

Blast-Furnace-Gas Control for Power Station

PITTSBURGH, PA.—A complex combustion system fires a twin-boiler installation for the 53,000-kw steam-electric power station at the General Savio Steel Mill in San Nicolas, Argentina. Fuels applied in succession are coke breeze, blast furnace gas, coke oven gas, and both heavy and light fuel oil, with provisions for future firing of pulverized coal to replace the heavy fuel oil. Control of the blast furnace gas offered the greatest challenge, report engineers of Hagan Chemicals & Controls, Inc. (Hagan Building, Pittsburgh 30, Pa.), who developed a combination electric-electronic-pneumatic system. Included are: a variable-resistance transducer using a Zener diode; an electropneumatic converter which receive the transducer output after amplification and acts to shut off the blast furnace gas when the pressure falls below a set limit; and other controls which automatically cut in the next available fuel.

CIRCLE 158 ON READER-SERVICE CARD

Here you see a specially trained North American crew carefully loading a Burroughs computer. Professional crews such as these move electronic computers valued as high as three-quarters of a million dollars each.

Why Burroughs uses North American Van Lines for shipping electronic computers

"Because of North American's superior handling and delivery service, they are awarded a large portion of all shipments of our expensive and delicate electronic computers," asserts W. A. Reed, Traffic Manager, ElectroData Division, Burroughs Corporation.

He goes on to say, "North American's custom floor-to-floor delivery service is especially important in transporting items of this size and weight. Their crews have the necessary equipment and know-how to place the computers exactly where our customers desire. And by using North American's services we can ship our computers almost 100% assembled."

This is just one more example of how North American Van Lines' Kid-Glove handling and complete service all the way eliminates the many problems involved in shipping High Value Products.

Call your local North American agent and get the facts first hand. He'll be glad to talk with you about *your* product moving problems without obligation.

NOW ON TV!

See "Championship Bridge" with Charles Goren and Alex Dreier Sunday afternoon on most ABC-TV stations.

North American
WORLD-WIDE MOVING
LAND · SEA · AIR

CIRCLE 25 ON READER-SERVICE CARD

NORTH AMERICAN VAN LINES, Inc. / World Headquarters / Dept. 18-6 / Fort Wayne, Indiana

In Canada, North American Van Lines Canada, Ltd., Pickering, Ontario . . . In Europe, North American Van Lines, Europe, GMBH, Mannheim, Germany

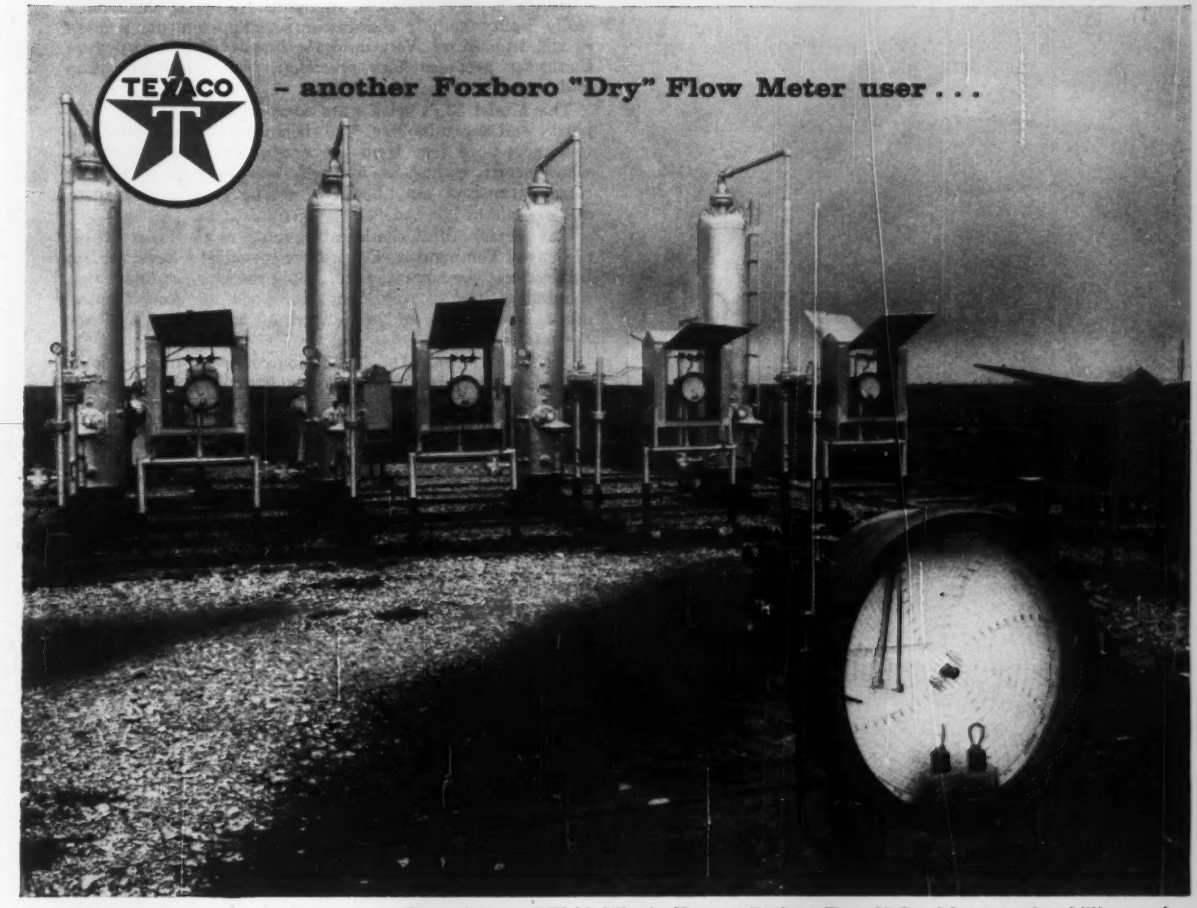
Here is Why!

You can dispense with oil filters and dust filters when you install ®Nash® Clean Air Compressors. You can save the cost of maintaining these devices. You can greatly reduce instrument maintenance costs. For the Nash employs no internal lubrication, therefore no troublesome oil is in the delivered air. Moreover, air from a Nash is thoroughly washed and cooled as it passes thru the pump. Dust in the plant atmosphere, even fly ash, is immediately removed.

®Nash® Clean Air Compressors are simple, with only one moving element. No valves, gears, pistons, sliding vanes, or other enemies of long life and constant performance complicate a Nash. No aftercoolers are needed. You will find it profitable to investigate these pumps, now.

No oil filters.
No dust filters.
No internal lubrication to contaminate air handled.
No internal wearing parts.
No valves, pistons, or vanes.
Non-pulsating pressure.
Original performance constant over a long pump life.
Low maintenance cost.

NASH ENGINEERING COMPANY
370 WILSON, SO. NORWALK, CONN.



Texaco's Stowell Field, Winnie, Texas—Foxboro Type 37 Dry Meters used on billing service.

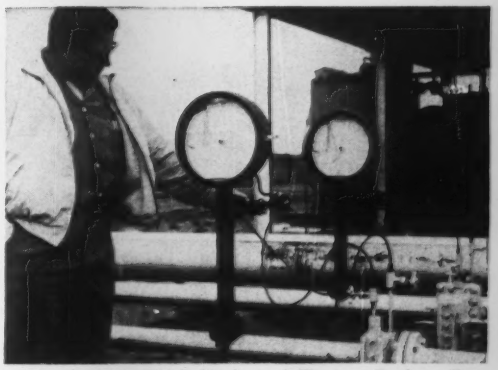
Foxboro "Dry" Meters eliminate costly mercury maintenance, damage from overrange

There are over 50 Foxboro T/37 "Dry" Flow Meters in Texaco's East Texas gas fields. Some measure flare gas and gas flow to compressors while others handle billing assignments.

Foxboro "Dry" Meters give users two distinct benefits. First—since there is no mercury to clean, or replace, they're cheaper to maintain. Second—since the T/37's unique diaphragm assembly can't be damaged by overrange, line surges and winter freeze-ups cease to be a problem.

As for accuracy—monthly checks have found only two of the 50 meters that ever needed recalibration.

Producers, pipeliners, plant men—they're all reporting superior flow metering with Foxboro Dry Flow Meters. Get full details from your nearby Foxboro Field Engineer. Or write for Bulletin 7-15. The Foxboro Company, 4612 Norfolk Street, Foxboro, Massachusetts.



Texaco's Cody Field, Clarkwood, Texas—Foxboro Dry Meters measuring flare gas, and gas flow to compressor.

FOXBORO

REG. U.S. PAT. OFF.

CIRCLE 26 ON READER-SERVICE CARD

What a build!

. . . solid state components

in New Fenwal

Temperature Controller combine precision with extra reliability

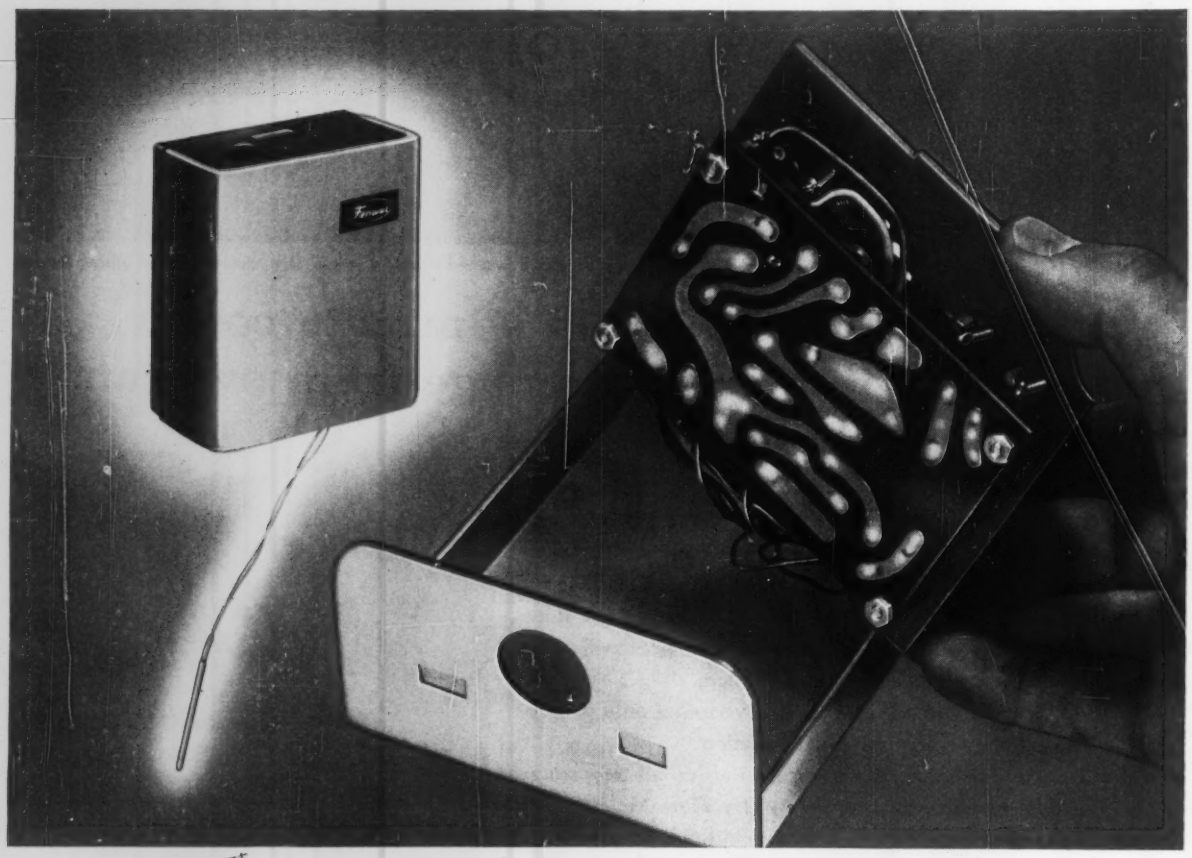
Here's a new, low-cost temperature controller that's really built "solid": thermistor sensing element, printed circuit, transistors. *No wonder the Fenwal 535 Temperature Controller provides high precision, trouble-free operation and long life!*

The Model 535's solid state components pay off in simplicity and dependability. The thermistor sensor mounts up to hundreds of feet from the controller using uncompensated electric wiring; has virtually limitless life; feeds into a rugged transistor amplifier. *No moving parts . . . nothing to wear out!*

The Model 535 is the latest advance in the low-cost line of Fenwal Temperature Controllers specifically developed to fully exploit the advantages . . . rapid response, compact size, reliability . . . of solid state components. *And Fenwal, alone, has integrated production of both controllers and thermistors.*

Use the Fenwal Model 535 Controller for fast response and close control of temperatures from −25°F to +600°F in plastics, packaging, or other critical applications. Get full details from a Fenwal Sales Engineer or write for catalog. Fenwal Incorporated, 3612 Pleasant Street, Ashland, Mass.

Single point Model 535 Fenwal Temperature Controller has 2°F setting accuracy and sensitive operating differentials from 0.4°F to 1.2°F. Current capacity: 5 amps. 115 volts AC — 10 amp. model later in 1959.



ANOTHER EXAMPLE OF HOW **Fenwal** CONTROLS TEMPERATURE . . . PRECISELY

CIRCLE 27 ON READER-SERVICE CARD

Important news for owners of CEC's 5-114 recording oscillograph

NEW RAPID-ACCESS DATARITE MAGAZINE

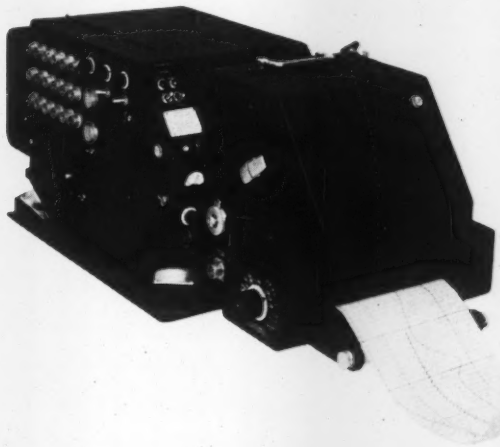
provides developed, dried, fully visible records almost instantly

Here is the DATARITE Magazine many of you owners of CEC's 5-114 Recording Oscillograph have been waiting for: The new 5-047. This DATARITE Magazine attaches directly to your 5-114. The result is a data-processing tool with all the capabilities needed for modern dynamic tests—especially attractive for low-budget programs.

RAPID-ACCESS . . . THE 5-047 DATARITE Magazine provides the shortest access time of any known process, and yields records of high trace contrast and permanency. The Magazine automatically develops and dries oscillograms as quickly as data are recorded. Ready-to-read test results are available almost simultaneously with the occurrence of events under study.

The 5-047 recording speeds are variable from .45 to 28.8 ips. Fully developed and visible record is available in 0.7 second at 28.8 ips record speed. There is a generous capacity of 400 feet of conventional thin-base recording paper, combined with writing speeds up to 20,000 ips. Power requirement is 115 v, 60 cps, 1500 watts for the combination of the 5-047 and the 5-114.

For complete details call your nearest CEC sales and service office, or write for Bulletin CEC 1500-X27.



Electro Mechanical Instrument Division CEC

CONSOLIDATED ELECTRODYNAMICS. *360 Sierra Madre Villa, Pasadena, California*

CIRCLE 28 ON READER-SERVICE CARD

unusual capabilities and stability

64 channels in 60″

On these two pages eight fully transistorized Model 850-1500P Preamplifiers appear actual size—each measures approximately 2″ x 7″ x 14½″. In racks of eight, 64 preamplifiers take only 56″ of panel space, and a blower unit another 4″. Necessary power and chopper excitation is provided by a completely transistorized Model 858-500P Power Supply that mounts at the rear of each 8-preamplifier unit, so that no additional panel space is required.

INPUT CHARACTERISTICS
Input circuit guarded, floating, isolated from output, can be grounded. Input impedance 200,000 ohms min. (Preamplifier also available at extra cost with 4-step attenuator with gains of 10, 20, 50 and 100 and smooth gain control to reach any intermediate setting.)

BANDWIDTH
DC to 70 cps (−3 db).

RISE TIME
25 ms to 99.9% of steady state value.

OUTPUT CHARACTERISTICS
Floating, independent of input, can be grounded.
Capabilities: ±1 v across 300 ohms, DC to 70 cps
±1.5 v across 300 ohms, DC to 40 cps
Output impedance 100 ohms. Output is across 300 ohm internal load, shunted by internal 4 mfd capacitance. Part or all of this resistance and capacitance can be supplied externally, in any combination to suit your application.

LINEARITY
±0.1% of full scale output (2 volts)

GAIN
100 (10 mv input for 1 volt output). Preamplifier with gain of 1000 (1 mv input for 1 volt output) also available on special order. Gain stability ±0.1% for min. of 24 hours.

INPHASE REJECTION RATIO
120 db at 60 cps, 160 db at DC, with 5000 ohms unbalance in source.

INPHASE TOLERANCE
250 VDC, 220 VAC

NOISE
2 uv peak-to-peak referred to input (measured over DC to 100 cps). Noise plus ripple for full scale signal not to exceed ±0.1% of signal (measured wide band-ripple is 880 cps).

DRIFT
±2 uv referred to input, at constant ambient temperature, after 30 minutes' warm-up. Input drift temperature coefficient ±0.2 uv/°C, max.

OVERLOAD RECOVERY
Preamplifier recovers from fully blocked condition within 20 milliseconds after removal of signal. 10 volts of signal at input will not damage preamplifier.

POWER REQUIREMENTS
Each Preamplifier requires 2.5 watts; Model 858-500P Power Supply handles up to eight Preamplifiers.

New Data Preamplifier model 850

$462.50
per channel, complete

Each Model 850-1500P Preamplifier costs $400, each Power Supply for every eight Preamplifiers, $500. Consider the substantial savings over equipment with comparable specifications – when economy "per channel" is multiplied by the number of channels you're using. (All prices are F. O. B. Waltham, Mass., within continental U. S. A.)

What distinguishes this data preamplifier from others is *not* its specifications *alone*— but the *combination of this performance with high reliability, practical cost* and *small size.* Together, they make the Sanborn Model 850-1500P the logical choice for data processing systems in which tens or hundreds of channels of information must be handled.

Completely transistorized, the 850-1500P is designed for amplifying low level inputs such as thermocouple, strain gage and resistance bridge outputs. Typical outputs include digital voltmeters, tape recorders, scopes and other readout devices.

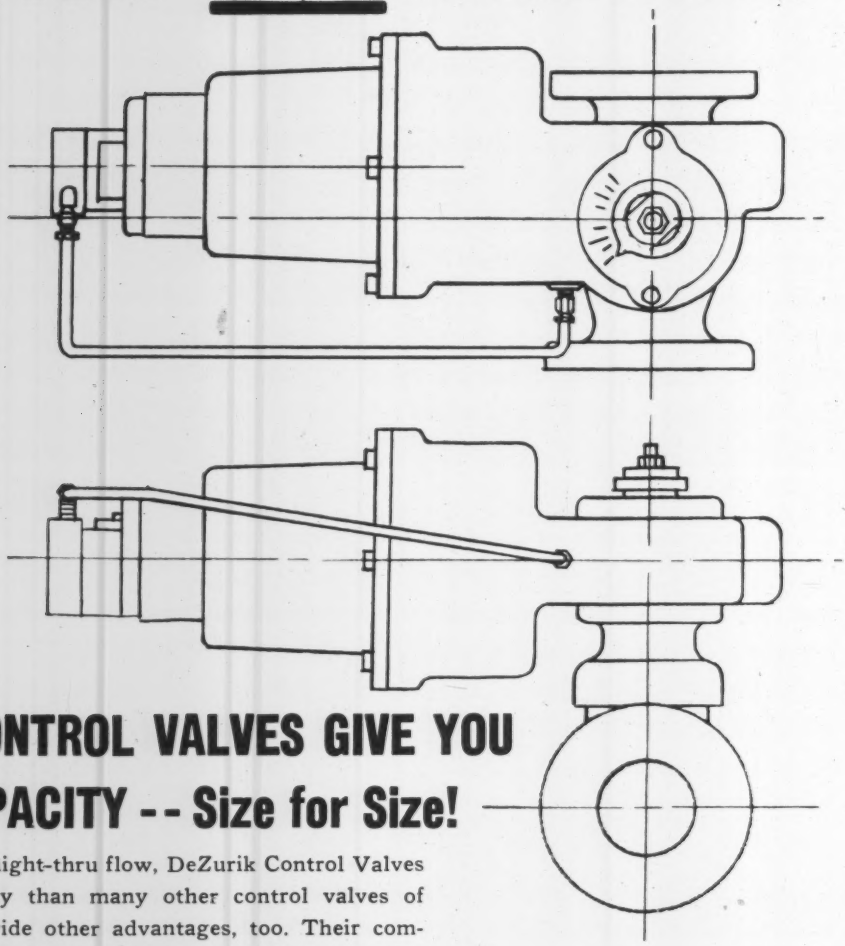
Complete engineering data and application assistance is available from Sanborn Company. Contact your nearest Sanborn Industrial Sales-Engineering Representative, or write the main office in Waltham, Mass.

-1500P

SANBORN COMPANY
INDUSTRIAL DIVISION
175 Wyman St., Waltham 54, Mass.

CIRCLE 29 ON READER-SERVICE CARD

TRY THIS FOR SIZE!



DeZURIK CONTROL VALVES GIVE YOU HIGHER CAPACITY -- Size for Size!

Because of their straight-thru flow, DeZurik Control Valves permit higher capacity than many other control valves of equal size. They provide other advantages, too. Their compact size makes installation easy in practically any location. They deliver dead-tight shut-off despite solids in the flow. They have high rangeability, with a flow characteristic usable down to the shut-off position. They have provision for manual operation—at no extra cost. Their leak-proof stem seal eliminates a source of trouble common to many other valves. AND because of their basically simple design, DeZurik Control Valves are equipped with a positioner often at a cost less than an ordinary control valve without a positioner.

DeZurik Control Valves are available in sizes ½" thru 20" in pneumatic, hydraulic or electric models. They are produced in almost any castable metal.

INSTRUMENT ENGINEERS!

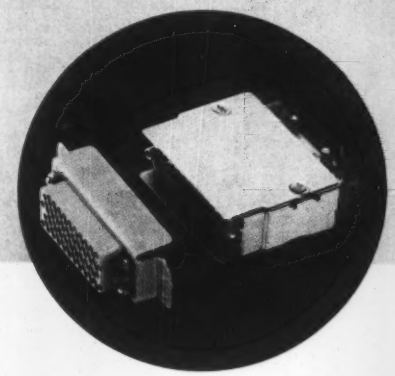
The complete story of DeZurik Control Valves is told in Bulletin 150. Get your copy from the DeZurik representative in your area, or write Dept. CV.

DeZURIK CORPORATION
SARTELL, MINNESOTA

CIRCLE 30 ON READER-SERVICE CARD

WHEN YOU NEED CONNECTORS...CALL YOUR NEARBY CEC CONNECTOR REP.

THROUGH SALES OFFICES IN MAJOR CITIES THROUGHOUT THE COUNTRY a wide variety of rugged, lightweight CEC electrical connectors are available off-the-shelf. Standard types for flush or surface mounting...with jack screws or guide pins...straight or right-angle hoods... in 26-, 34-, 42-, 50-, 75-, or 104-pin configurations...are available—special types designed to your specifications.



SERIES 500-C multi-contact connectors, shown at left, feature easy-to-assemble snap-in contacts which simply push into place, yet permit fast, easy removal with a simple hand tool. Four-prong retention spring in each contact resists an axial pull of at least 20-lbs....equal to a cable-harness strength of 1,500 lbs. for a 75-pin connector.

CEC representatives in the cities listed below are ready to fill your requirements for dependable, advanced-design connectors. Call today and get detailed information.

Arizona, Phoenix—ALpine 2-8468
California, Pasadena—MUrray 1-8421
Connecticut, New Haven—STate 7-0115
Florida, Miami—PLaza 1-4692
Orlando—through Winter Park—MIdway 4-4413
Georgia, Atlanta—TRinity 5-8908
Illinois, Chicago—AUstin 7-2089
Indiana, Indianapolis—FLeetwood 9-5374
Iowa, Cedar Rapids—EMpire 2-6302
Kansas, Wichita—MUrray 2-2731
Maryland, Blandensburg—UNion 4-4722
Massachusetts, Lexington—VOlunteer 2-2500
Michigan, Detroit—VErmont 8-3460
Minnesota, Minneapolis—FEderal 9-0707
Missouri, Kansas City—WEstport 1-4884
St. Louis—VOlunteer 3-6550
New Jersey, Union City—UNion 7-3204
New York, Fayetteville—NEptune 7-9531
North Carolina, Charlotte—EXpress 9-3673
Ohio, Cincinnati—MEirose 1-9210
Dayton—AXminster 8-4261
Westlake—SUperior 1-1855
Pennsylvania, Wynnewood—MIdway 2-9100
Texas, Arlington—CRestview 4-0761
Washington, Seattle—MAin 4-1673

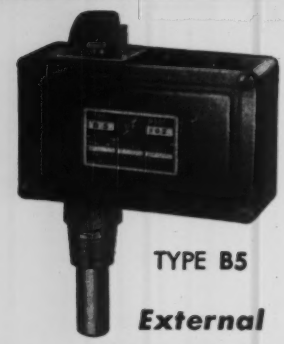
Electro Mechanical Instrument Division

CEC

CONSOLIDATED ELECTRODYNAMICS *360 Sierra Madre Villa, Pasadena, Calif.*

CIRCLE 31 ON READER-SERVICE CARD

B5 *Local Mounted* **TEMPERATURE CONTROL**



TYPE B5

External Adjustment

KNOB AND DIAL

UNITED ELECTRIC's type B5 control allows temperature settings to be made by rotating a single turn knob and pointer against a calibrated dial. It is a compact, inexpensive, precision-built control designed for numerous applications including hot water tanks, internal-combustion engine cooling systems, boilers, deaerators, etc. Uncalibrated, internally adjusted versions of the type B5, designated type C7, are also available. Complete information on these and other local mounted controls may be had by requesting the *new* Catalog Section 100. Information contained in this new catalog will prove extremely helpful to all design engineers.

Calibrated Ranges	100° or 200° F. between 0° and 425° F. limits.
Thermal Assemblies . . .	Various immersion lengths . . . liquid-filled seamless brass bellows operate by hydraulic action.
Switch Ratings	15 amps. at 115 or 230 volts AC, also 20 amps. or DC switches available on specification.
Switch Types	N.O., N.C., Double Throw, no neutral position.
Electrical Connection . .	To internally located terminal block by clearance hole in enclosure.
Size & Weight	4¼" x 1½" x 6⅛", weighs approx. 12 oz.
Mounting	For local mounting by ½" male NPT on immersion element, turning radius is 3⅛".
Enclosure	Aluminum case with black wrinkle finish.

UNITED ELECTRIC manufactures a complete line of temperature, pressure, and vacuum controls. Modified or custom-built units can be made to suit your specifications. Consult a UE application engineer today.

Write for Bulletin No. 2-1 for more data on the B5 control or request the new Catalog Section I which covers all UE local mounted units.

United Electric Controls
COMPANY
SCHOOL STREET WATERTOWN MASS.

CIRCLE 32 ON READER-SERVICE CARD

stock report

Further information may be obtained from the Research Department, Bache & Co., 36 Wall Street, New York 5, N. Y.

NEW YORK STOCK EXCHANGE

PRICE RANGE FOR 1959 THRU NOVEMBER 19, 1959

	High	Low	Price As Of 11/20/59
ACF Industries	57	47 5/8	48 7/8
Aeroquip Corp.	34 3/4	23 5/8	30
Allis Chalmers	38 3/4	26 7/8	34 3/8
American Chain & Cable	61 3/4	47 3/4	50 1/4
American Machine & Foundry	52 3/8	45 1/8	49 3/4
American Machine & Metals	59 3/4	41	46
American Optical	53 1/2	38 3/8	47 7/8
American Tel. & Tel.	89	75 1/8	77
Ampex Corp.	126 1/4	61 1/4	134 7/8
Bausch & Lomb Optical	40 1/2	27	35 3/4
Beckman Instruments	74 3/4	36 1/4	65
Bell & Howell	77 3/8	53 1/4	72 1/8
Bendix Aviation	89	61	74
Boeing Airplane	46 1/2	29 1/8	32 1/8
Bullard	24 7/8	15 1/2	16 1/2
Bulova Watch	20 5/8	13 3/8	16 1/2
Burroughs	45 3/4	28 3/4	33 5/8
Carborundum	56 3/4	37 3/8	47 3/4
Cincinnati Milling Machine	47 5/8	35 1/4	36 1/2
Clevite	40 3/8	24 3/4	40
Columbia Broadcasting System	48 3/4	35	40 3/4
Consolidated Electrodynamics	45 1/2	30 3/4	39 1/8
Consolidated Electronics	47	37 1/4	47
Cornell Dubilier	30 1/2	17 3/4	19 3/4
Corning Glass	150 1/2	89 3/4	142 3/4
Curtiss Wright	41 1/4	27 1/8	32
Cutler-Hammer	94 1/4	59 1/2	87 5/8
Daystrom	49 3/4	34	41 1/2
Douglas Aircraft	59 3/4	36 7/8	38 5/8
Eastman Kodak	102 3/4	75	102 3/4
Eaton Mfg.	42 (New)	36 3/4	40 1/2
Electric Auto-Lite	55 1/2	36 1/4	51
Elgin Watch	14	9 3/4	11 1/4
Emerson Electric	69 7/8	48 1/8	66 1/4
Food Machinery & Chemical	55 3/8	40	49 5/8
Gamewell	39 1/4	27	30 1/4
Garrett	50 7/8	38	43 7/8
General Controls	39 1/4	24	27 1/4
General Dynamics	66 1/2	42 7/8	44 5/8
General Electric	84 3/4	74	83 3/4
General Instrument	38 3/8	16 1/2	29 1/8
General Mills	37 5/8	30 1/2	31 1/2
General Precision Equipment	53 5/8	31 1/2	52
General Railway Signal	39 1/4	26 3/4	28 1/8
General Tel. & Elec.	79	60	75 7/8
General Time	104 1/2	35	87
General Tire & Rubber	86 3/4	44 1/8	80 7/8
International Bus. Machines	488	385 1/2	407 1/2
International Tel. & Tel.	45 1/2	28	40 1/2
I-T-E Circuit Breaker	50 1/2	36 5/8	40 1/2
Lear Inc.	23 1/4	9 1/8	18 1/2
Litton Industries	149	72 5/8	147 1/2
Lockheed Aircraft	39 3/4	24 5/8	30 5/8
Magnavox	39 1/2	32 3/4	36 1/2
Mallory	48 3/4	36 1/8	38 7/8
Minneapolis-Honeywell	150	111 1/2	126 3/4
Minnesota Mining & Mfg.	155	111 1/2	155
Motorola	157 1/2	57 1/2	152 1/4
National Acme	63 1/2	50 1/8	52 1/2
National Cash Register	80	55 1/8	64
Neptune Meter	39 5/8	27 3/4	29
North American Aviation	52 5/8	30 1/4	35 5/8
Northrop Aircraft	44 3/4	24 5/8	29 5/8
Otis Elevator	83	61 1/2	78 3/8
Philco Corp.	36 3/4	21	27 1/2
Radio Corp. of America	71	43 1/8	66
Raytheon Mfg.	73 7/8	43 1/2	51
Reliance Electric	64	42 5/8	65
Rheem Mfg.	25 3/4	17 3/4	21 3/4
Robertshaw Fulton	54 1/4	31 5/8	55
Royal McBee	24 3/8	16	19
Sangamo Electric	51 1/2	35	37 1/4
Siegler Corp.	45 1/4	23 1/8	34 1/2
Sperry Rand	28 1/4	21 1/8	23 1/4
Square D	37 1/4	26 7/8	32 3/4
Standard Coil Products	23 3/4	13 3/4	15 5/8
Starrett (L.S.)	23 7/8	20	20
Stewart-Warner	64	42 1/2	60 1/4
Telautograph	13 3/8	9	9 1/8
Texas Instruments	192 1/2	61 1/4	192 1/2
Thompson-Ramo-Wooldridge	70 1/4	52	58 1/2
Tung-Sol Electric	54 1/4	34 1/8	42 1/4
Underwood Corp.	30 7/8	19 1/8	23 7/8
Union Carbide Corp.	150 1/2	120 1/2	138 1/2
United Shoe Machinery	58 3/8	45 5/8	57 1/4
Varian Associates	47 1/2	26 3/4	48 1/4
Wallace & Tiernan	52 7/8	36 1/4	42 1/2
Western Union	47 1/2	29 3/4	45 1/4
Westinghouse Air Brake	38 1/2	27 1/2	29 3/8
Westinghouse Electric	99 3/8	70 1/2	98
Worthington Corp.	84 1/2	59 1/2	63 3/4

(1) Not Traded — Bid and Asked.
These prices and price ranges are given as printed in the Wall Street Journal.

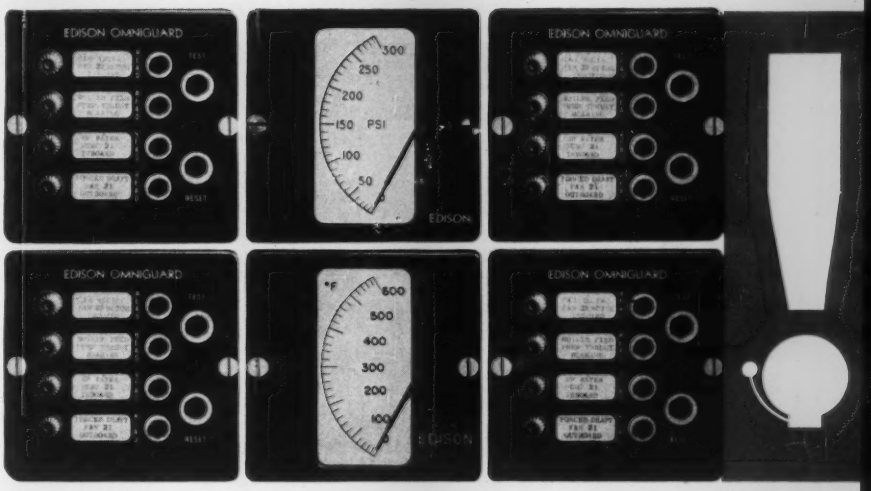
AMERICAN STOCK EXCHANGE

PRICE RANGE 1959 THRU NOVEMBER 19, 1959

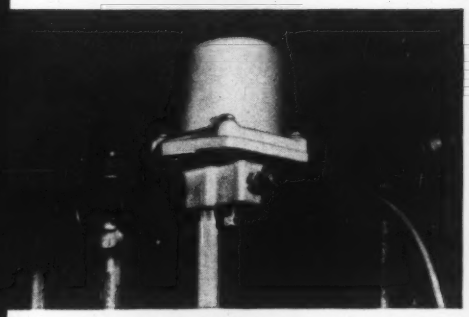
	High	Low	Price As Of 11/19/59
American Meter	47 1/4	38	46 1/8
Aro Equipment	29 3/4	20 3/4	25
Barry Controls "B"	26	13 3/4	19 1/2
Belock Instruments	22 7/8	10 3/8	18 1/8

Continued on page **1796**

GUARD ALL CRITICAL PRESSURES AND TEMPERATURES WITH THOMAS A. EDISON LOW-COST, OMNIGUARD WARNING SYSTEM



Here is a versatile, highly-reliable continuous warning and monitoring system. By simply pushing a button on this panel you obtain a reading of *key pressure* and *temperature* points throughout your plant. In addition, this system provides instantaneous warning when pressure or temperature deviates from pre-set limits.

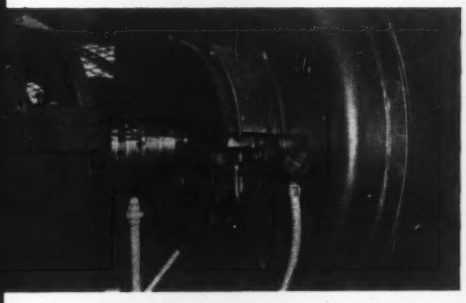


Compact, reliable Resistance Pressure Detector transmits changes in pressure to central control panel.

PRESSURE

With the Edison Omniguard system you can monitor gas, fluid or vapor pressure. Heart of the system is a rugged, accurate, pressure detector which converts pressure directly to electrical resistance—requires no millivolt conversion—no amplifier. For pressures under 60 PSI a precision capsule is the sensing element. From 60 to 3000 PSI special bourdon tube elements are used.

When pressure changes, resistance varies and this deviation is transmitted to the control panel. Units operate over ambient temperatures of 32° to 150°F. Control panels are available with a wide variety of scales and are equipped with both normally open and normally closed alarm contacts to operate any type of auxiliary device or to automatically shut down machinery or process.



Rugged, accurate Resistance Temperature Detector guards against overheating of this motor bearing.

TEMPERATURE

Edison Omniguard also provides reliable protection from overheating. You can monitor the temperature of bearings, gases and liquids in critical equipments or processes. Reliable Edison Resistance Temperature Detectors have no moving parts and give instantaneous warning when limits are exceeded. Unlike other systems which only scan, Omniguard is continuously monitoring. You can obtain exact readings of temperatures in all parts of your plant from one central control panel.

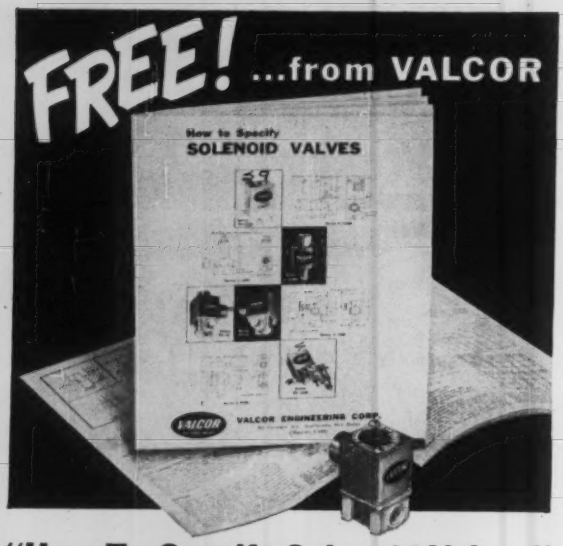
For greater flexibility and reliability each detector circuit is completely independent. If one circuit is damaged, all other circuits remain "on guard." When changes or additions are required they can be accomplished quickly and easily.

Thomas A. Edison Industries

INSTRUMENT DIVISION

24 LAKESIDE AVENUE, WEST ORANGE, N. J.

CIRCLE 33 ON READER-SERVICE CARD



"How To Specify Solenoid Valves"

A complete, illustrated guide for calculating flow and pressure drop characteristics...how to determine the most suitable valve configuration...what type of sealing principle is best for you...how to eliminate costly over-specifying. Invaluable to engineering and purchasing personnel.

WRITE TODAY FOR YOUR FREE COPY.

VALCOR SOLENOID VALVES

VALCOR ENGINEERING CORP.

5366 CARNEGIE AVE., KENILWORTH, N. J.
CHESTNUT 5-1665

CIRCLE 34 ON READER-SERVICE CARD

MARSHALLTOWN

DIAPHRAGM GAUGE

FOR ACCURATE PRESSURE MEASUREMENT IN OUNCES OR INCHES OF WATER

Marshalltown Figure 83 is an extremely sensitive gauge that uses a carefully seasoned bronze diaphragm to accurately measure very low pressures. It is used extensively on many types of natural gas installations for checking low pressures.

Available in standard dials (reading in inches of water) 0-15" -0-30" -0-60" -0-100" -0-160" . . . also in ounce graduated dials from 15 ounces to 5 pounds. 2½", 3½" and 4½" dial sizes mounted in black enameled steel case.

Write for details and price. LOOK TO MARSHALLTOWN FOR ONE OF THE MOST COMPLETE LINES OF INDICATING PRESSURE GAUGES MADE!

MARSHALLTOWN MFG. COMPANY
MARSHALLTOWN 3, IOWA

CIRCLE 35 ON READER-SERVICE CARD

American Stock Exchange

Continued from page 1794

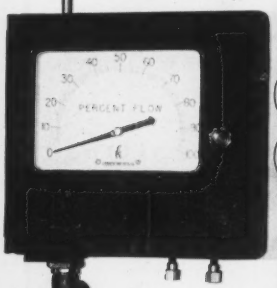
Benrus Watch	9	5 3/4	5 7/8
Breeze Corp.	3/8	6 1/8	7 1/8
Clark Controller	30 3/8	19 5/8	21 5/8
Clarostat Mfg.	15 1/4	4	14 3/8
Clary Corp.	10 7/8	5 3/4	7 1/8
Du Mont Laboratories	9 7/8	6	8 1/8
Dynamics Corp. of America	12 3/4	4 5/8	10 1/2
El-Tronics	2 1/4	1	1 3/8
Electronics Corp. of America	16 7/8	7 1/2	9 3/4
Fairchild Camera & Instrument	263 1/4	50 3/4	250 7/8
General Transistor	45 3/8	29	34 1/2
Globe-Union	27 3/4	20 1/4	24 1/4 Bid 24 1/2 Asked
Hazeltine Corp.	33	23 1/2	27 7/8
International Resistance	22 3/4	7	19 1/2
Loral-Electronics	32 1/8	28 5/8	30 1/4
National Research	39 1/2	15 3/8	21 3/8
New Haven Clock	5 3/8	1 1/2	2 1/4
Nuclear Corp. of America	4 1/4	1 3/4	2 1/8
Philips Electronics, Inc.	59 1/4	23 1/2	41 1/2
Pneumatic Scale	67	32	46
Servo Corp. of America	13 1/2	14 5/8	21 7/8
Servomechanisms	18 1/4	9	10 5/8
Statham Instruments Inc.	43	23	34 1/8
Victoreen Instrument Co.	19 7/8	6 7/8	11 1/2
Waltham Prec. Instrument Co.	4 3/8	2 1/8	2 3/4

(1) Not Traded — Bid and Asked.

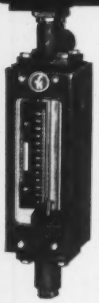
These prices and price ranges are given as printed in the Wall Street Journal.

OVER THE COUNTER	Quotation as of 11/19/59 Bid	Asked
Aerovox Corp.	14 1/4	15 3/4
Argus Corp.	32 1/2	33 3/4
Black Sivalls & Bryson Inc.	20 1/2	22
Eitel McCullough	28	28 3/4
Electro Instruments	58	62
Electronics Associates	29	31
Erie Resistor Corp.	7 1/4	8 1/4
Fisher Governor Co.	16	16 3/4
Foxboro Company	70	73
Giannini Controls	30 3/4	32 3/4
Hagan Chemicals & Controls	34 1/2	35 3/4
Industro Transistor	13 1/2	15 1/2
Liquidometer Corp.	9 1/4	10 1/2
W. L. Maxson	11 1/2	12 1/8
Penn Controls	22 3/4	23 3/4
Speer Carbon, Inc.	22	22 3/4
Sprague Electric	58	60
Taylor Instruments	35	36 1/4
Telecomputing Corp.	9 1/4	10 1/4
Topp Industries	9 1/2	10 3/8
Vitro Corp. of America	11	11 3/4

NEW/IMPROVED



PNEUMATIC TRANSMITTING ROTAMETER



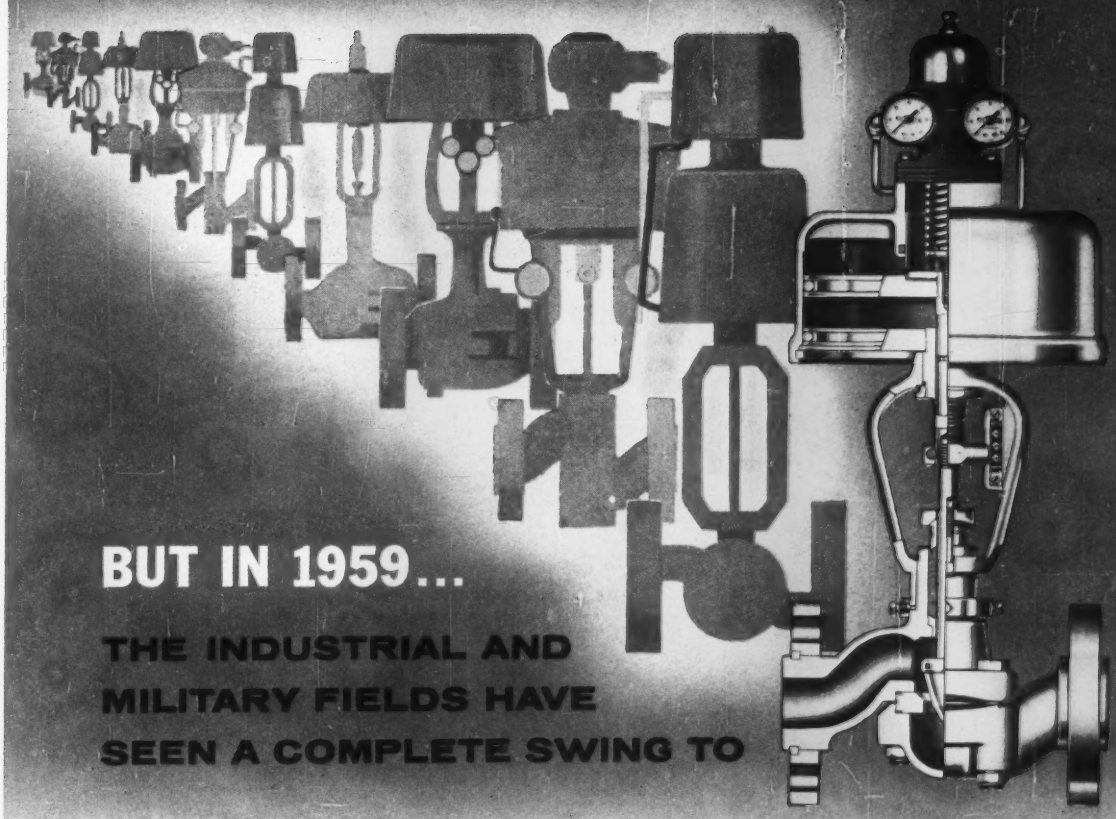
New "position-balance" type Transmitter . . . air-signals fluid rates of flow to remote recorders, controllers . . . incorporates *exclusive* calibration adjustments (no cams) and drag-eliminating magnet design . . . scale suitable for any calibration . . . offers other features of real value all detailed in new Bulletin 18N. Write for a copy.

Schutte and Koerting COMPANY
INSTRUMENT DIVISION
2225 STATE ROAD, CORNWELLS HEIGHTS, BUCKS COUNTY, PA.

CIRCLE 36 ON READER-SERVICE CARD

IN 1948...THEY SAID IT COULDN'T BE DONE

...that split body, single seat construction would never be the accepted design for industrial or military control valves.



BUT IN 1959...

THE INDUSTRIAL AND MILITARY FIELDS HAVE SEEN A COMPLETE SWING TO

CONTROL the ANNIN WAY

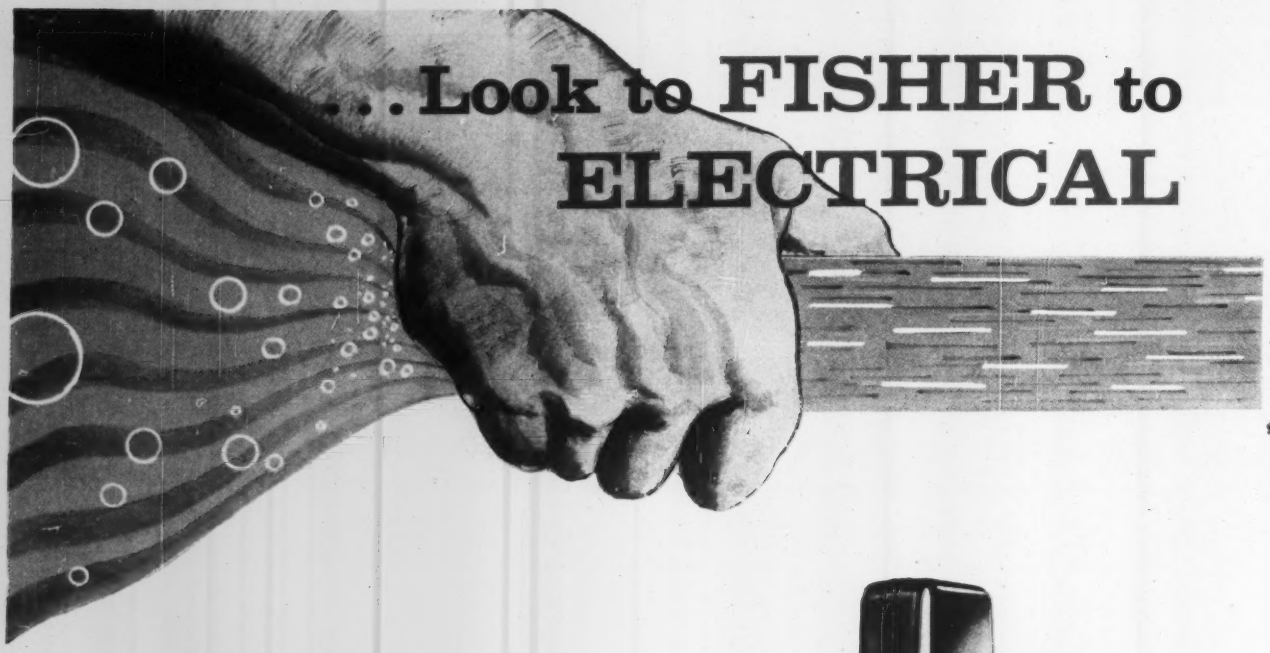
In 1948 split body construction and powerful high speed, precise positioning pneumatic piston actuators were available from only one source—Annin. Today, more than a decade of accumulated experience in this type of valve design makes Annin features and performance records the best in the valve industry. Contrary to published statements by critics ten years ago, Annin-type construction is now available from many sources. But when tempted to consider *mere-replicas* of Annin valves, remember this—they might give you a few Annin features, but when you specify Annin Valves you get them all!

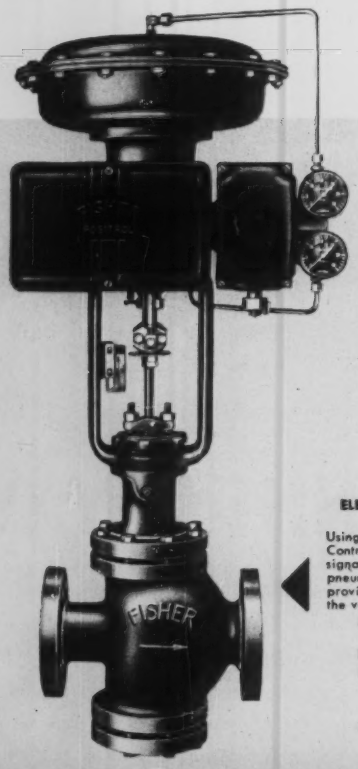
Annin VALVES

THE ANNIN COMPANY
1040 South Vail Avenue
Montebello, California

CIRCLE 37 ON READER-SERVICE CARD

. . . Look to FISHER to ELECTRICAL





THE ELECTRO-PNEUMATIC POSITIONER "E-POSITROL"

Using a conventional Fisher diaphragm Control Valve, the E-Positrol receives a Ma signal and translates this to a proportional pneumatic signal to a positioner which provides the speed and power to operate the valve.

Input Current: 1-5 ma; 4 to 20 ma, 10 to 50 ma D.C.

Linearity—1% of full scale.

Resolution-Sensitivity—0.1% of input range.

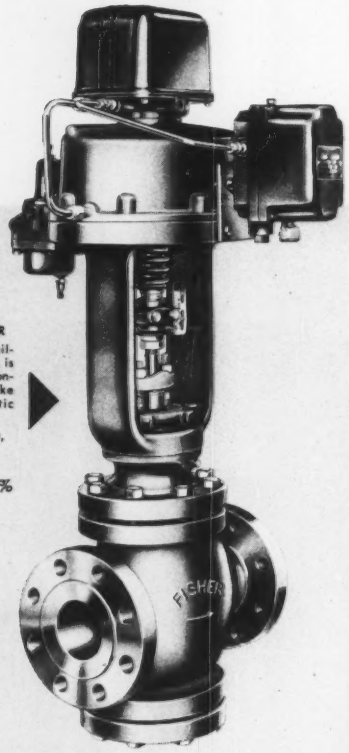
THE PNEUMATIC OPERATED PISTON "P.O.P." WITH ELECTRO-PNEUMATIC TRANSDUCER

The compactness, speed and power available from the FISHER Series 470 P.O.P. is readily made available in electrical control systems with the use of the yoke mounted Type 545 Electro-Pneumatic Transducer.

Input Current: 1 to 5 ma, 4 to 20 ma, 10 to 50 ma, d.c.

Linearity—1% of Full Range

Resolution Sensitivity—Less than 0.1% of Input Range.



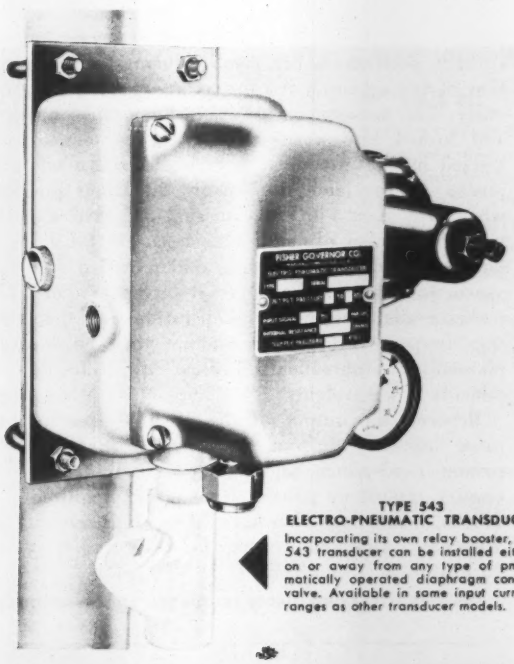
IF IT FLOWS THROUGH PIPE ANYWHERE IN THE WORLD . . . CHANCES ARE IT'S CONTROLLED BY . . .

CIRCLE 38 ON READER-SERVICE CARD

supply the muscles for your CONTROL SYSTEMS

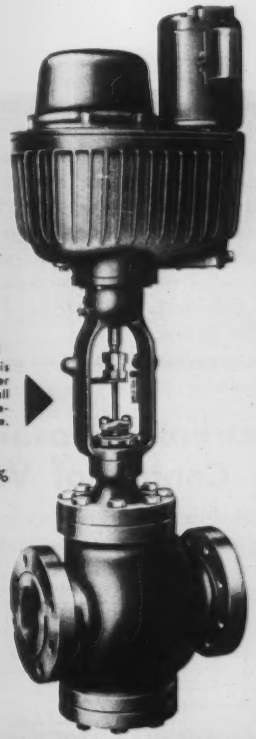
The old adage, "a chain is as strong as its weakest link" can be equally applied to the "muscle" or more correctly the final control element on any control loop. The importance of a control valve in an electronic system should never be considered lightly and that is why you should look to Fisher for assurance in furnishing dependable and accurate control valves for your electrical or electronic system.

Described below are three types of actuators that offer an exceptionally practical and economical approach for control valves in electrical control loops.



TYPE 543
ELECTRO-PNEUMATIC TRANSDUCER

Incorporating its own relay booster, the 543 transducer can be installed either on or away from any type of pneumatically operated diaphragm control valve. Available in same input current ranges as other transducer models.



THE TYPE 350
ELECTRO-HYDRAULIC ACTUATOR

In electrical control systems where air is not available or desirable, the Fisher Electro-Hydraulic Actuator provides all the necessary requirements for a dependable and accurate control valve.

Maximum Stem Thrust..2000 pounds
Stroking Speed.....0.37 in./sec.
Resolution Sensitivity...less than 0.05%

FISHER® Controls
SINCE 1880

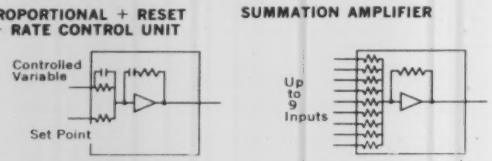
FISHER GOVERNOR COMPANY
Marshalltown, Iowa / Woodstock, Ontario / London, England
BUTTERFLY VALVE DIVISION: CONTINENTAL EQUIPMENT CO., CORAOPOLIS, PA.

CIRCLE 38 ON READER-SERVICE CARD

briefs

Solid State Magnetic Analog Computer Control

A typical PowrMag control system consists of four basic elements: (1) Input Transducers . . . (2) Analog Control Computer . . . (3) Remote Control Stations . . . (4) Final Control Elements . . . The Computer is built from magnetic modules that add, subtract, multiply, integrate and differentiate . . . These units are



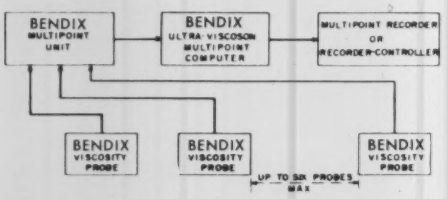
composed of operational amplifiers plus passive network components such as resistors, potentiometers, etc. All components plug in and are interchangeable to obtain whatever control function is desired. These units, plus the patchboard, form the modularly constructed analog computer . . . A basic general purpose amplifier may be converted to a controller by easy addition of reset or rate packages . . .

Interconnecting the system, via color-coded electrical cable, the patchboard requires no solder connections or terminal boards—all connections are made by taper pins . . . (*From new 6-page Bulletin MSP-163, Hagan Chemicals & Controls, Inc., Box 1346, Pittsburgh 30, Penna.*)

FOR THIS LITERATURE CIRCLE 159 ON READER-SERVICE CARD

Electronic Measurement and Control of Viscosity

The Bendix Ultra-Viscoson consists of a viscosity sensing probe, and an electronic computer. This instrument actually measures the mathematical product



of viscosity and density in four ranges . . . 0-50, 500, 5000 and 50,000 centipoises x grams/cc. However, in most cases the density of process liquids does not vary appreciably with respect to viscosity variations and specification limits. Therefore, in these instances, the density can be considered to remain constant . . .

The probe acts as a transducer. It shears the liquid under measurement and measures the damping effect, or "viscous drag" of the liquid. The actual sensing element consists of a thin strip of metal. One end is a magnetostrictive alloy and the other end, which is exposed to the process is stainless steel . . .

The computer sends out a short pulse of current to a coil which is situated inside the probe and around the thin blade. The resulting magnetic field excites the magnetostrictive member and causes the blade to vibrate . . . (*From new 16-page Booklet "Bendix Ultra-Viscoson", Bendix Aviation Corp., Cincinnati Div., 3130 Wasson Rd., Cincinnati 8, Ohio.*)

FOR THIS LITERATURE CIRCLE 160 ON READER-SERVICE CARD

Digitizer With A Memory

The unit is not only a precise analog-to-digital converter (ADC), but also a storage accumulator of time, events, pieces or quantities . . .

The Mem-O-Tizer contains an integral input shaft and first stage code drum. Additional drums, as required, are geared to the first drum. Each drum is composed of concentric cams. Each cam is profiled with a series of high, intermediate and low faces. Solenoid-operated "sensors", each with a simple position-locking device, sense the drum profile. Each sensor closes either of two switches in the high or low position. No switch closure occurs in the intermediate position. A detent wheel on the drum is engaged to accurately position the cam profile during the initial motion of the solenoid. All drums are sensed simultaneously. The sensors are positioned, switches operated and locked into position, and the sensors are retracted in 0.50 second . . . Solenoid-controlled interposing fingers latch the sensors into their positions when in contact with the cam surfaces. With this feature any number of measurements can be taken simultaneously and instantaneously and recorded with low-speed, low-cost, hard-copy reproducing systems. This makes available to industrial operations real time readings in process variables whether they be recorded manually or automatically without any electronic components in the system . . .

Between the output of the Mem-O-Tizer and the usual accessory readout equipment (visual indicator, printer, card punch, tape punch or computer), no accessory circuit or power elements are required . . . (*From new 4-page Brochure "The Digitizer with the Memory," Automation Div., Telechrome Mfg. Corp., 26 Edison St., Amityville, L. I., N. Y.*)

FOR THIS LITERATURE CIRCLE 161 ON READER-SERVICE CARD

Correction

In the Brief "Understanding Transistors" No. 174 on Reader-Service card which appeared in the November issue of I&CS we failed to mention that the "Handbook of Transistor Fundamentals" (Stock No. 37K 389) is available from Allied Radio Corp., 100 N. Western Ave., Chicago 80, Ill. at a price of 50c.

Engineered Dehydration in Pneumatic Systems

Sponge explains dew point ○
Clean air on low flow ●
Mag-Pneu-Power Trap ■
Refrigifilter: Inside story ◆

○ "Dew point" defined

Are you sure you use the terms "dew point" and "relative humidity" correctly? If there's any doubt, write for your copy of "THE DEW POINT STORY." A simple bath sponge analogy clarifies these terms in simple, easy-to-read language.

● Not a trace

What low-cost desiccant dehydrators are designed to provide clean, vapor-free air or gas to pneumatic equipment on dead end or low-flow service? Answer: Hankison Dehydrafilters.

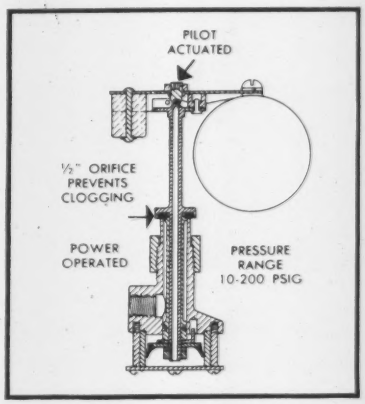
With water adsorption capacity at 28%, and obtaining dew points as low as −67 F, Dehydrafilters effectively eliminate costly steam or electric tracing of the air lines. Several models are available. Capacities of 1 SCFM at 100 PSIG to 25 SCFM at 6000 PSIG can be accommodated.

CM-1 Dehydrafilter. Cutaways show air inlet and outlet at top, desiccant and cartridge at bottom.

■ A well-planned trap

Looking for a non-clogging trap? Note the drawing (top, next column) of the mechanism in our Mag-Pneu-Power Trap. Rising condensate pushes against the magnetically-held float until it snaps free. Pressure in the pneumatic system then drives the piston, which opens the discharge valve. Condensate is discharged in a split second through the large ½" orifice. It's simple – and trouble-free. For the occasional cleaning that's required, just open the blowdown petcock in case (not shown).

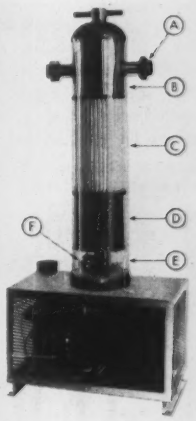
Mag-Pneu-Power Traps are used to discharge condensates and entrainments from all types of compressed air and gas lines, and to lend valuable assistance to air and gas dehydrating equipment. Stainless steel models are available for corrosive applications.



◆ Tells all

At right you see a demonstration model of the Hankison Refrigifilter. It gives you the inside story on obtaining instrument quality compressed air without cooling water, and regardless of ambient temperature variance.

In the unique Refrigifilter "package", incoming air at (A) is precooled in the counterflow heat exchanger (B). It then goes to the condenser-evaporator (D) where coils circulating Freon lower the temperature to 35° F *at pressure*, causing moisture and oil vapors to drop out into the collection chamber (E). Here the Mag-Pneu-Power Trap (F) discharges them through ½" orifice. From the condenser-evaporator, air passes through radial fin filter cartridge (C), which removes dirt, scale, and other solid contaminants. Thoroughly dried and cleaned, the air goes back into the counterflow heat exchanger where it is reheated and sent into the lines.



The Refrigifilter is simple, compact, costs less and does more than similar devices. It's easy to install, guarantees you micro-clean, dehydrated, oil-free compressed air all the time. Request Bulletin F-100 for the whole story—an exciting one indeed for anyone who uses pneumatic systems.

HANKISON CORPORATION, COLLEGE & PIKE, CANONSBURG, PA.

There's something here that interests me. Please send me more information about

- ☐ Dew Point
- ☐ Dehydrafilters
- ☐ Mag-Pneu-Power Automatic Traps
- ☐ Refrigifilters

NAME _____ TITLE _____

COMPANY _____

STREET _____

CITY _____ ZONE _____ STATE _____

Hankison

FOR DEW POINT CIRCLE 39; DEHYDRAFILTERS CIRCLE 146; MAG-PNEU-POWER CIRCLE 147; OR REFRIGIFILTERS CIRCLE 148.

NEW MARTIN-DECKER PRECISION TEST GAUGES

Designed for the Ultimate in Accurate Pressure Measurement

Write for descriptive brochure M-28A

Consider These Advantages:

- 360° Calibration provides 25% greater scale length.
- Saves over 100 square inches of panel space.
- Ni-Span C Bourdon tube corrects temperature effect.
- Tube tip bleed is standard equipment.
- .15% full scale accuracy.
- Movement calibrated to dial, uniform increments.
- Capacities to 15,000 psi.

Select territories available to test equipment or gauge distributors. Write direct to C. L. Howard, Industrial Sales Manager.

M/D MARTIN-DECKER CORP.
LONG BEACH, CALIFORNIA

CIRCLE 40 ON READER-SERVICE CARD

JEWELS *for* INDUSTRY. . .

By MOSER JEWEL COMPANY, pioneer industrial jewel manufacturer for over 50 years.

- HIGHLY POLISHED STEEL PIVOTS AND STAFFS
- HARD ALLOY WELDED TIPS
- NON-MAGNETIC STAFFS
- DIAMOND POINTS

FOR INFORMATION ON HOW WE MAY FILL YOUR REQUIREMENTS

Write to . . .

MOSER JEWEL COMPANY

P.O. Box 150 • Perth Amboy, N. J.

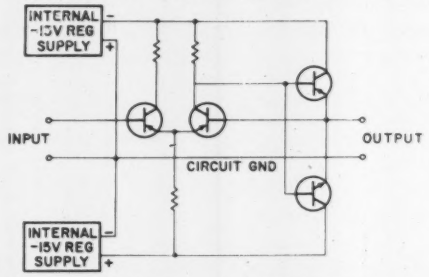
"Manufacturers of all types of Industrial Jewels"

CIRCLE 41 ON READER-SERVICE CARD

BRIEFS—CONTINUED

Solid State Galvanometer Driver Amplifier

The Model 92 DC Amplifier is especially designed to "fill the gap" between low power voltage sources and high frequency galvanometers requiring a substantial amount of driving power. Typical voltage sources are high gain DC amplifiers, telemetering receivers, demodulators, detectors, oscillators, transducer-de-

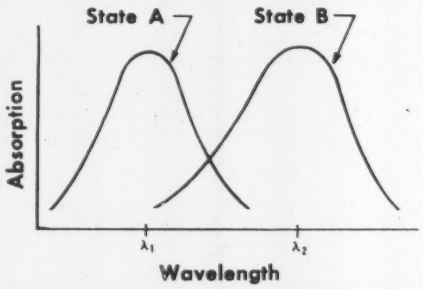


modulator combinations, etc. High frequency galvanometers require up to 100 ma of current, which these typical voltage sources cannot provide . . . Circuitry which is electrically isolated from chassis permits operation of this amplifier at potentials up to 300 volts above ground . . . (*From new 20-page catalog and supplement, Video Instruments, 3002 Pennsylvania Ave., Santa Monica, Calif.*)

CIRCLE 162 ON READER-SERVICE CARD

Photochromism

A family of dyes—called "photochromic"—can be changed reversibly between two distinct color states . . . The change occurs in response to energy from light sources which exhibit suitable spectral characteristics. Interaction with light alters the molecular structure of the dyes and yields different absorption . . . This optical switching property is illustrated by the dia-

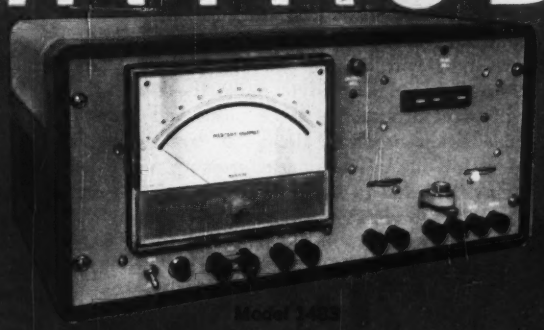


gram which shows relative absorption for various wavelengths . . . Photochromic properties occur only when the dyes are dissolved in an appropriate solvent . . . By means of a National proprietary process called "micro-encapsulation", the liquid is dispersed into very fine droplets which are encased by an impermeable wall, such as a thin layer of gelatin . . . (*From new 4-page Brochure "Photochromism", National Cash Register Co., Main & "K" Sts., Dayton 9, Ohio.*)

CIRCLE 163 ON READER-SERVICE CARD

a new type
primary standard
for measuring
AC/DC power

INTRODUCING



THE WESTON ELECTRONIC WATTMETER

- Transfer accuracy between DC and AC is within 0.01%
- Unprecedented versatility and reliability

CHECK THESE FEATURES:

- **NEGLIGIBLE STATIC FRICTION** between pivot and jewel bearing to affect accuracy. A small-amplitude vibration is fed constantly to the sensing element—makes possible resolutions down to .01% — 1/5 the resolution of the best indicating meter.
- **NO SPRING FATIGUE** — Springs have been eliminated.
- **TEMPERATURE COMPENSATED** — reduced self-heating errors.
- **LOW EDDY CURRENTS** — due to ferrite shields. Frequency compensated.
- **NO MUTUAL INDUCTANCE ERRORS** — The coils are oriented at 90°.
- **SUSTAINED ACCURACIES DOWN TO 10% POWER-FACTOR.**
- **ONLY ONE POTENTIOMETER** needed for DC Standardization—other wattmeters need two Type K pots, multiplying costs . . . and errors.
- **READ-OUT VERSATILITY** — can actuate remote indicators, digital meters; drive strip-chart recorders, integrators; used in parallel or alone.

With the development of its Model 1483 Electronic Wattmeter, Weston now brings to AC and DC power measurement a degree of accuracy which extends even beyond the traditional accuracy of Weston's indicating type dynamometer wattmeters. With quick, precise operation, the Model 1483 provides a low impedance DC output that can be measured by present day highly accurate techniques. Truly, here's a new concept in quality and capability.

For full information, contact your local Weston representative . . . or write to Daystrom-Weston Sales Division, Newark 12, N. J. *In Canada: Daystrom Ltd., 840 Caledonia Rd., Toronto 19, Ont. Export: Daystrom Int'l., 100 Empire St., Newark 12, N. J.*

A DAYSTROM UNIT

WESTON *Instruments*

WORLD LEADER IN MEASUREMENT AND CONTROL

CIRCLE 42 ON READER-SERVICE CARD

Solenoid Valves

Each valve has a flow coefficient (C_v flow factor) for determining the flow capacity or pressure drop,

Formulas

FOR GASES

$$SCFH = 1360\ Cv \sqrt{\frac{(\text{Press. Drop})}{(460° + °F.)} \frac{(\text{Inlet Press. P.S.I.A.})}{(\text{Spec. Grav.})}}$$

$$\text{Pressure Drop} = \left[\frac{(460° + °F.)\ (\text{Spec. Grav.})}{\text{Inlet Press. P.S.I.A.}}\right] \left[\frac{SCFH}{(1360)\ (Cv)}\right]^2$$

Specific Gravity of Gas at 60°F.	
Coke Oven Gas	0.4
Ammonia	0.59
Nitrogen	0.98
Air	1.0
Propane	1.59
Butane	2.0

(P.S.I.A. = lbs. per sq. in. ABSOLUTE. Add 14.7 lbs. to pressure.)

when necessary. The following formulas, by substituting the allowable pressure drop and flow requirement, can be used to easily determine the required valve size . . . (*From new 16-page Catalog V-5076, Automatic Switch Co., Florham Park, N. J.*)

FOR THIS LITERATURE CIRCLE 164 ON READER-SERVICE CARD

Magnetic Tape

Top features of the new tape are a unique magnetic coating formula, a pre-coating process, micro-polishing, and extra-precise slitting . . . A newly developed form of ferric oxide, new high-temperature binders, and antistatic agents are ingredients of CEC's carefully guarded tape coating compound formula. A significant advance in the state of the art is the elimination of plasticizers from the formula . . . In the precoating process, a smooth, level, non-magnetic precoat is applied to the Mylar base. This precoat accurately equalizes variations in thickness and serves as a firm bonding agent to anchor the oxide . . . (*From new 4-page Bulletin 1619, DataTape Div., Consolidated Electrodynamics, 360 Sierra Madre Villa, Pasadena, Calif.*)

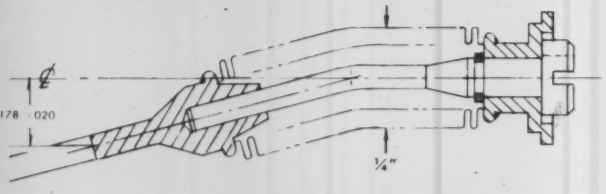
FOR THIS LITERATURE CIRCLE 165 ON READER-SERVICE CARD

Pneumatic Positioning of Butterfly Valves

Let us assume that the pressure of the fluid being controlled has increased above the set point. The bellows unit will receive an increased signal from the controller and expand to move the beam. The beam will pivot around the fixed point and simultaneously uncover the nozzle of Relay "B" and cover the nozzle of Relay "A". The nozzle pressure will increase in Relay "A" due to the restriction created by the beam over the nozzle. Through relay action, the air pressure to the top of the piston, "A" in the sketch, will be increased. Relay "B" will be reacting to the change in beam position to decrease the pressure to the

SEALED ADJUSTOR

MAINTAIN VACUUM WHILE ADJUSTING HERMETICALLY SEALED UNITS WITH ROBERTSHAW ADJUSTOR ASSEMBLY

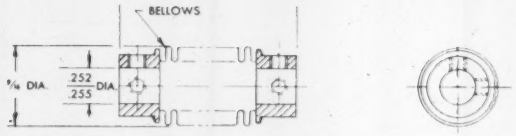


Now . . . adjust or recalibrate hermetically sealed instruments without breaking the vacuum. Robertshaw Adjustor Assemblies permit 360° adjustment. Heat treated steel shaft inside miniature seamless metallic bellows transmits torque from external source to internal mechanism. Leak tested on mass spectrometer. Unit shown is a zero adjustor for an aircraft instrument. Available as custom units with bellows as small as ¼" O.D. WRITE FOR ENGINEERING DATA SHEET F1012!

CIRCLE 43 ON READER-SERVICE CARD

FLEXIBLE COUPLING

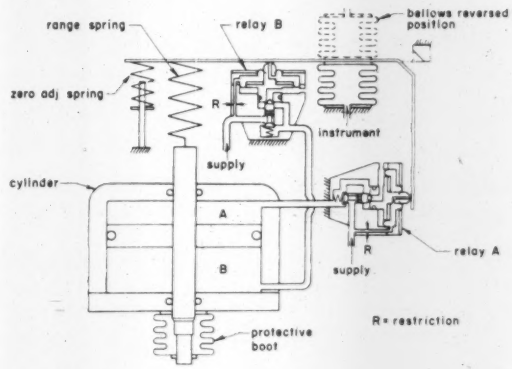
ELIMINATE BACKLASH, END-PLAY! ABSORB VIBRATION, SHOCK WITH ROBERTSHAW FLEXIBLE COUPLINGS



Servomechanisms, instruments and similar drive and control systems are the big users of these small, flexible units. Ideal for guarding against misalignment friction and bearing wear problems. Save space and weight. Cut down noise. Simplified design utilizes seamless metallic bellows, in choice of several metals, connected to two hubs. Sizes from 15/32" O.D. Stock sizes accommodate shafts from ⅛" to ½". Other sizes custom-engineered. WRITE FOR DATA SHEET F8012!

CIRCLE 44 ON READER-SERVICE CARD

under side of the piston, "B" in the sketch. Due to the unbalanced pressures acting on the piston, it will move down, changing the valve position as dictated by the controller. The piston movement is fed back to the beam by means of a range spring that is connected to the piston rod extension, thus preventing any further build-up of pressure in the cylinder. . . .



(From new 2-page Descriptive Sheet Gc-48, Continental Equipment Co., Div., of Fisher Governor Co., Coraopolis, Penna.)

FOR THIS LITERATURE CIRCLE 166 ON READER-SERVICE CARD

Bi-Variant Function Generator

The BIVAR function generator, (Model 1100-16A) is designed to give instantaneous solutions of quantities which are a function of two variables. With the

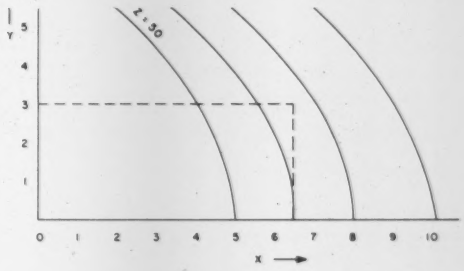


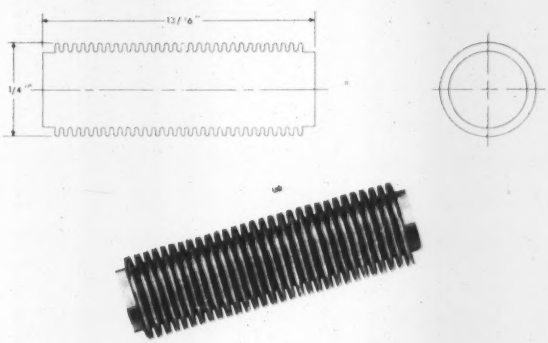
Figure 1: Plot of equation $z = y^2 + 10x$ for constant values of z.

BIVAR the family of curves are reproduced on a semiconductive plate using conductive ink. Lines of equal values of z are energized with d-c voltages scaled to represent the constant values of z. A conducting probe mounted on the Variplotter pen holder, which is positioned by the plotter arm and pen according to the values of x and y, measures the voltage corresponding to the value of z . . . *(From new 4-page Bulletin AC 909, Electronic Associates, Inc., Long Beach, N. J.)*

FOR THIS LITERATURE CIRCLE 167 ON READER-SERVICE CARD

MINIATURE BELLOWS

SAVE SPACE AND WEIGHT WITH RUGGED, MINIATURE ROBERTSHAW METALLIC BELLOWS

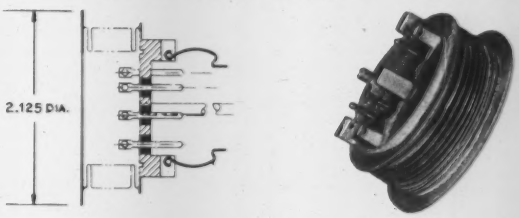


Seamless metallic bellows only ¼" and 5/16" O.D. permit further miniaturization in aircraft, missiles, instruments and other equipment. Available in a wide range of bellows metals to provide the desired strength and performance characteristics. Sensitive to temperature and pressure changes. Custom-engineered . . . but available in any quantity you need. Proved in dozens of miniaturized assemblies. **WRITE FOR BULLETIN F81012!**

CIRCLE 45 ON READER-SERVICE CARD

FLUID EXPANSION CAPSULE

THERMAL EXPANSION OF OIL CONTROLLED BY SPACE-SAVING ROBERTSHAW FORMSET® BELLOWS



A low spring rate and a large stroke per unit of length, provided by a special Robertshaw Metallic Bellows called Formset, made possible this expansion capsule used in airborne gyroscopes. This assembly absorbs the thermal expansion of the oil which encases the gyroscope. Low spring rate in the bellows permits low pressure in the gyro. Space savings of up to 90% in bellows length can be achieved with Formset Bellows. Custom-engineered for instruments, transformers, relays and other applications using any fluid. **WRITE FOR ENGINEERING DATA SHEET F1012!**

Robertshaw

BRIDGEPORT
THERMOSTAT DIVISION
Milford, Conn.

CIRCLE 46 ON READER-SERVICE CARD

CONSIDER...

Lockheed for telemetry

Out of Lockheed creative engineering sessions such as this come advanced design and proven performance in the field of telemetry. Lockheed's pioneer work on the X-17 project resulted in the first successful telemetering of vital data during re-entry. Research continues to provide even greater reliability of performance to meet present requirements.

The Lockheed Electronics and Avionics Division (LEAD) is currently conducting research in Frequency Modulated and Pulse Modulated Systems for industrial and military needs.

For proven reliability in telemetry components and systems, consider LEAD.

CIRCLE 47 ON READER-SERVICE CARD

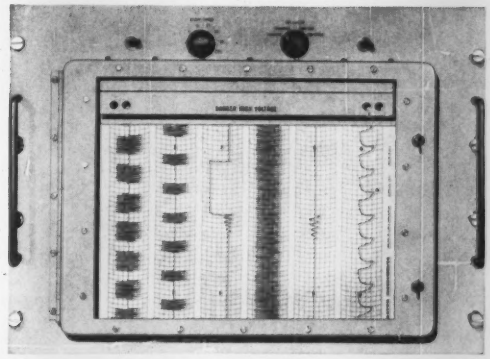
Look to Lockheed for LEAD*ership in Electronics*

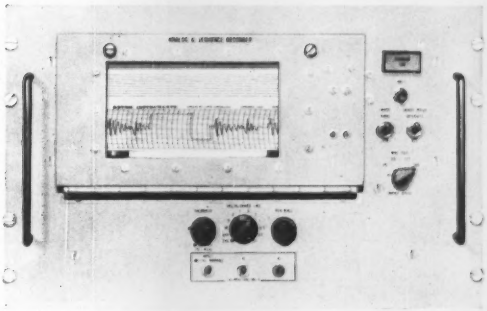
LOCKHEED ELECTRONICS & AVIONICS DIVISION

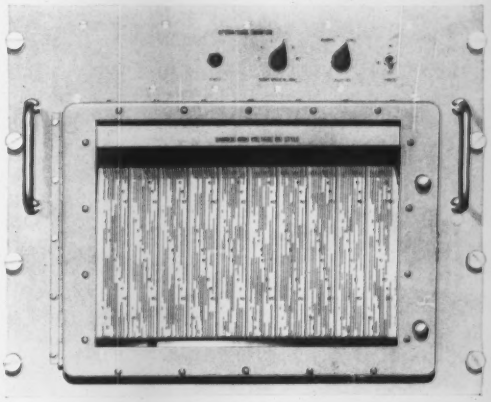
REQUIREMENTS EXIST FOR STAFF AND SUPERVISORY ENGINEERS

CIRCLE 48 ON READER-SERVICE CARD →

6201 E. Randolph St., Los Angeles 22







in direct writing recording systems

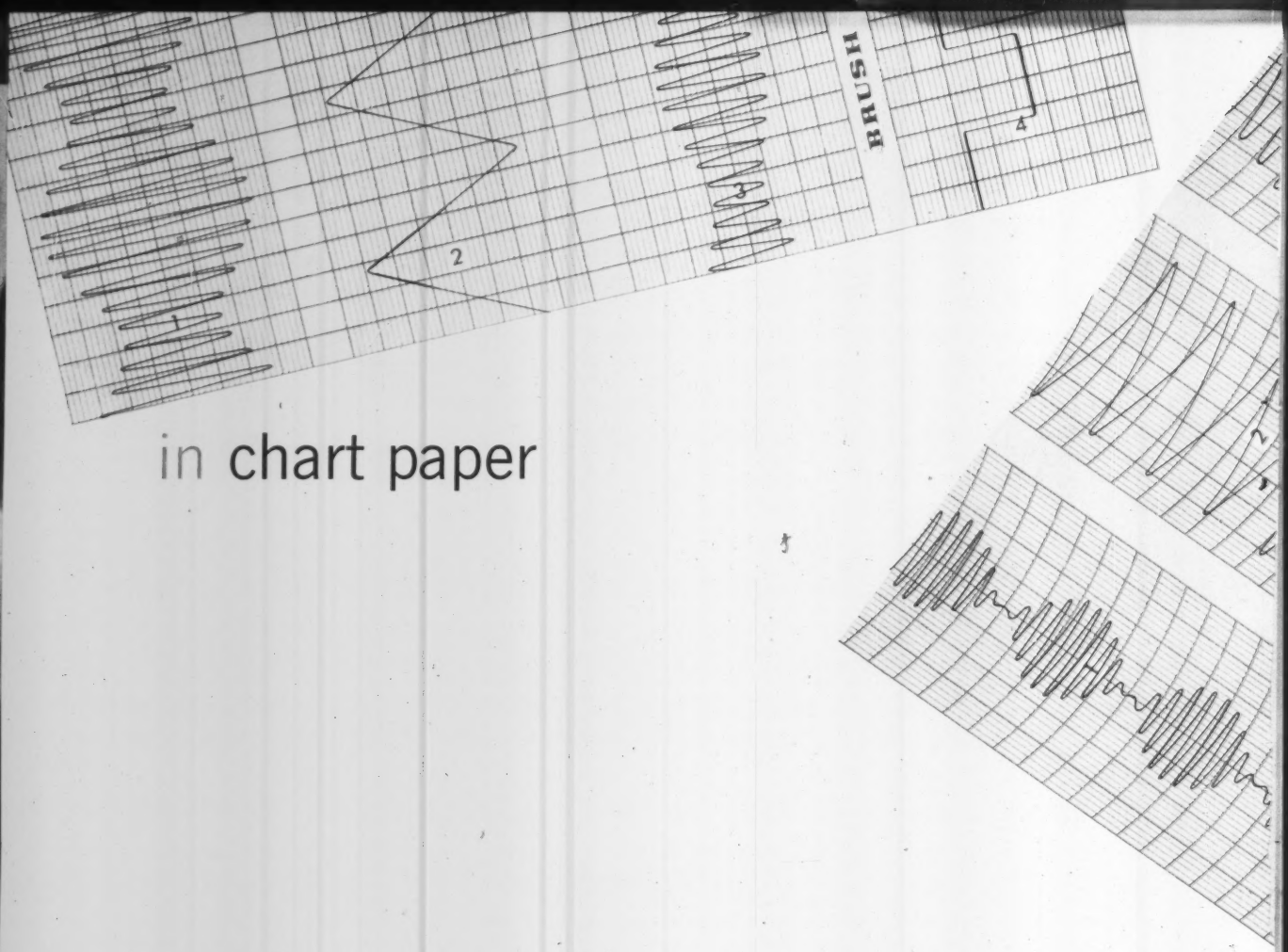
only Brush designs specifically for mil specs

From every nut and bolt to the shipping crate, fully militarized Brush Direct Writing Recording Systems are *originally* built to meet military specifications.

That's why they are performing every imaginable task of data acquisition and recording at U. S. and NATO installations throughout the world. These electric writing systems have proved their unexcelled reliability . . . from the Operations Monitor that will record 120 separate operations at the instant they occur . . . to the Analog and Sequence Recorder that simultaneously records both analog data and sequential events. And, they are built for maximum performance in the hands of non-technical personnel.

Brush equipment is already at work putting evaluation data in writing for a whole new generation of weapons. When the weapons become operational, Brush MIL Recorders are a vital part of the system. This experience is unique in the industry. *Before* prototype design becomes a problem—call, write or wire Brush for complete details.

brush INSTRUMENTS
DIVISION OF
CLEVITE CORPORATION
37TH AND PERKINS CLEVELAND 14, OHIO

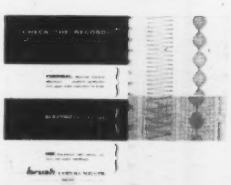


in chart paper

there is a difference

brush INSTRUMENTS
DIVISION OF
37TH AND PERKINS CLEVITE CORPORATION CLEVELAND 14, OHIO

Only Brush Chart Paper is designed as an integral component of precisely engineered Brush Direct Writing Recording Systems. The full potential of these systems cannot be realized unless *all* of the original components are utilized. They're engineered as a *total* entity. Imitation papers cannot match the precision ruling, dimensional stability and super-smoothness of Brush Chart Paper. Take no chances—specify *Brush* and you can rely on your records being accurate, permanent, easily read and easily reproduced. Stocks available from strategically located branches and sales representatives throughout the United States and Canada.



Write for samples of actual tracings on Brush Chart Paper. Ask for "Check the Record".

book reviews

The Theory of Numbers, and Diophantine Analysis by Robert D. Carmichael [c 1914 and 1915], published in 1959 as one book by Dover Publications, Inc., 180 Varick St., New York 14, N. Y., 94 plus 118 p., 8″, paperbound $1.35. Although not requiring more than a firm foundation of high-school math both parts of the book offer excellent exercises to the student and teacher alike, at all levels of ability.

CIRCLE 168 ON READER-SERVICE CARD

On Numerical Approximation, edited by Rudolph E. Langer, [c 1959] University of Wisconsin Press, 811 State St., Madison, Wis., 462 p., 9″, $4.50 paperbound. Proceedings of Symposium conducted by Mathematics Research Center, U. S. Army, at the University of Wisconsin, April 21-23, 1958.

CIRCLE 169 ON READER-SERVICE CARD

Principles of Optics by Max Born and Emil Wolf, [c 1959] Pergamon Press Inc., 122 East 55th St., New York 22, N. Y., 803 p. plus xxvi, 9¾″, clothbound $17.50. Intended to fill the same place in the English speaking world as the main author's German textbook, it incorporates results of recent advances in classical theory and is not a mere translation. Optics are presented deductively as a system based on Maxwell's equations.

CIRCLE 170 ON READER-SERVICE CARD

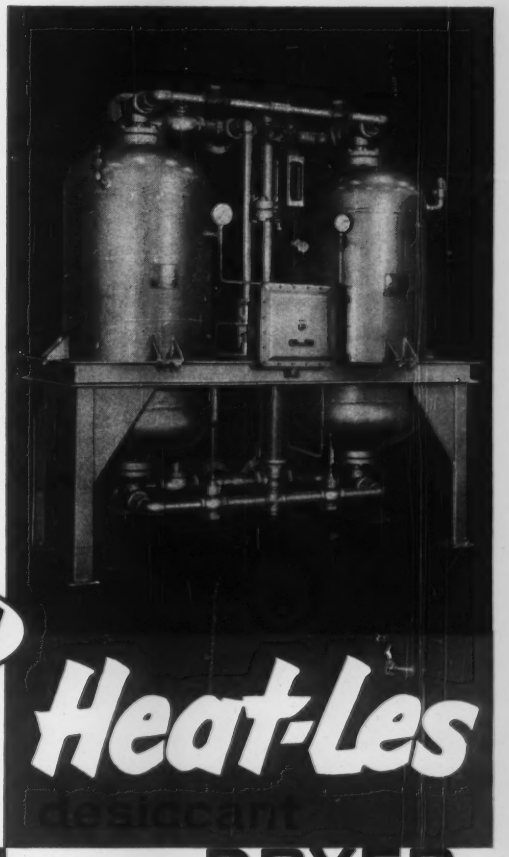
Encyclopedic Dictionary of Electronics and Nuclear Engineering by Dr. Robert I. Sarbacher, [c 1959] Prentice-Hall, Inc., 70 Fifth Ave., New York 11, N. Y., 1417 p., 9¾″, clothbound $35.00. With the rapid advance of the two subject sciences this dictionary (which has had the cooperation of thirteen professional societies and organizations) will prove of great value to scientists, manufacturers, technical writers, libraries, etc.

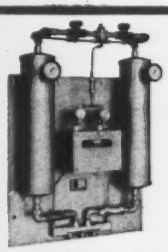
CIRCLE 171 ON READER-SERVICE CARD

Tool Engineers Handbook, second edition, edited by Frank W. Wilson and Philip D. Harvey, [c 1959] by American Society of Tool Engineers, McGraw-Hill Book Company, Inc., 330 W. 42nd St., New York 36, N. Y., 2289 p., 9″, clothbound $19.50. Revised under supervision of ASTE Technical Publications Committee, it includes modern materials, methods, and machines, and deals with topics such as spark machining, electrolytic grinding, surface cleaning by supersonics, etc.

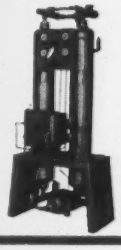
CIRCLE 172 ON READER-SERVICE CARD

some remarkable **FACTS** about the TRINITY Heat-Les desiccant DRYER





Heat-Les dryers are available in a wide range of capacities to meet all industrial and military needs.



1. **REJECTS OIL**—Eliminates the need for accessory oil filters and ensuing replacements of desiccant or filter cartridges.

2. **LOWER INITIAL COST**—Original equipment costs savings up to 50%, depending upon installation requirements.

3. **LOWER MAINTENANCE COSTS**—No heaters to service. Few moving parts. Designed for maximum life, minimum service requirements.

4. **COMPLETELY AUTOMATIC**—Requires no attention.

5. **DEWPOINTS AS LOW AS —180° F**—Standard guarantee—100° F at line pressure. Actual dewpoints below range of usual measurement.

Here's a working phenomenon so remarkably simple, yet so effective, you must see it to believe it. The Heat-Les Dryer is the practical answer to all industrial dynamic dehumidification needs.

WRITE FOR COMPLETE DETAILS...

Heat-Les Dryers are available in a wide range of sizes to meet practically all requirements, and are designed to operate at 30 to 6000 psig.

TRINITY

Heat and Heat-Les reactivated dryers.
Complete air supply and purging systems.

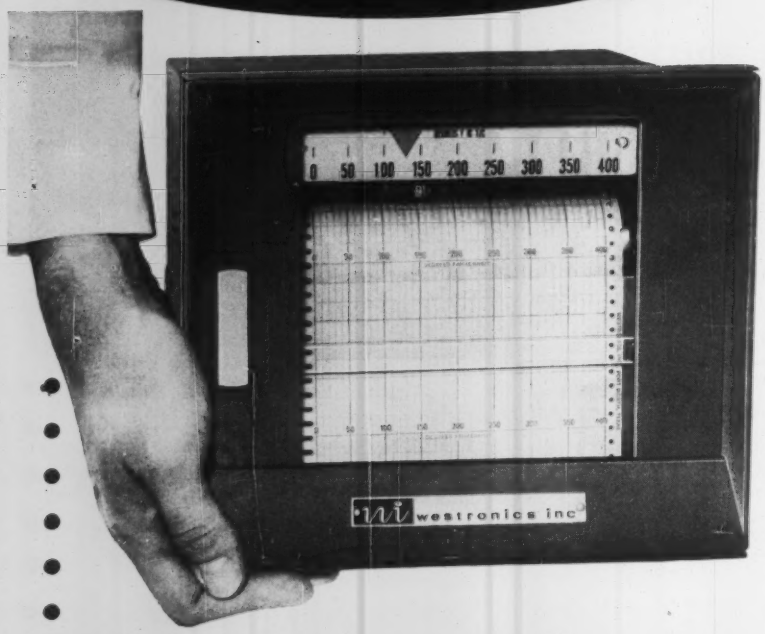
TRINITY EQUIPMENT CORPORATION, CORTLAND, NEW YORK

CIRCLE 49 ON READER-SERVICE CARD

←——CIRCLE 48 ON READER-SERVICE CARD

Another FIRST!

westronics®



MINIATURE
MULTIPOINT
RECORDER

12 POINTS ON 5 INCH CHART

SPECIFICATIONS ON PAGE 1811

CIRCLE 50 ON READER-SERVICE CARD

panhandle pete

Trends in Instrumentation

"Cuz," says Waldo Klapsaddle, Sales Manager of WESCO! at a recent buzz session, "The coming thing in this great automation age—here Waldo and the entire staff of WESCO! stood at attention, facing the East while little Mazda Klapsaddle (Waldo named her "Mazda" because she is so bright) read a passage from Milton H. Aronson's Book *Electronic Circuitry*—is the survey, the interview with men of distinction and the questionnaire which solves all problems. We must prepare for the future and time to do this is now!"

Here Waldo pounded on the desk to emphasize his point, narrowly missing a water pitcher and hitting a clutch of duck eggs he has been watching to hatch. "It is silly to prepare for the future," says Waldo, unperturbed by the mess, "In the future because the future gets here fast and then its the present and . . . er, anyhow, I've sent a questionnaire to the leaders of the electronic, pneumatic hydraulic and mechanical control people plus everybody in Long Bottom, covering all the questions facing our field in the future. We have systemated our answers on the T. R. System analyzer and O. J. Computer. WESCO! does another great service to the instrument industry by reporting these trends:

Question: Will more skill be required in the future to manufacture instruments?

Answer: 33% yes; 33% no; 33% blank

Question: Will more skill be required to service instruments?

Answer: 33% yes; 33% no; 33% blank

Question: Where will the greatest skill be required?

Answer: In manufacturing

and selling 33%; installing calibrating and servicing instruments 33%; blank 33%.

Question: What is the average rate at which the skill requirement rate is increasing?

Answer: 33% yes; 33% no; 33% blank—average 33%.

Question: Will this be the same in 1962?

Answer: 33% yes; 33% no; 33% blank.

Question: In 1982?

Answer: 33% yes; 33% no; 33% blank.

Question: In 2002?

Answer: 33% yes; 33% no; 33% blank.

Question: What fields are developing most rapidly:

Answer: Electronic and pneumatic 33%; hydraulic, mechanical—33%; blank, 33%.

Question: What skills will be needed most badly?

Answer: Electronic and pneumatic 33%; hydraulic and mechanical 33%; blank 33%.

Question: Is the need for technicians increasing?

Answer: 33% yes; 33% no; 33% blank.

Question: What are you doing to increase the reliability of instruments?

Answer: We are increasing the reliability of components and assemblies 33%; nothing 33%; blank 33%.

"IN THE JOB I HAVE IN MIND FOR YOU, YOU'LL FUNCTION AS A SORT OF SERVO-MECHANISM."

Question: What are you doing about serviceability of instruments?

Answer: We are making them easier to service 33%; nothing 33%; blank 33%.

Question: Where do you use your engineers?

Answer: In Engineering 33%; nowhere 33%; 33% blank.

Question: Where do you use your technicians?

Answer: In technical work 33%; nowhere 33%; 33% blank.

Question: To meet your future needs, where should there be greater educational emphasis on instrumentation?

Answer: In colleges and high schools 33%; technical schools and plants 33%; blank 33%.

Question: It has been said by a good source that the amount of service work required by automated equipment is inversely proportional to the amount of time spent on the equipment, which in turn is a function of the 3/2 power of the engineering skill used in designing it. Is this so?

Answer: yes, 33%; no, 33%; blank, 33%.

Question: According to Buckinham's Law of Exponential Extrusions, all constants, especially those obtained from engineering handbooks, are to be treated as variables. What is your findings on this matter?

Answer: 33% yes; 33% no; blank, 33%.

Questions: Are more surveys of this type needed by our industry?

Answer: Yes—66%; blank, 33%.

This survey clearly emphasizes the basic trends of our field—and nuts to the joker who sent back the blank survey.

Panhandle Pete

SPECIFICATIONS

westronics

MINIATURE MULTIPOINT RECORDER

SEE PHOTO ON PAGE 000

General: A recording potentiometer which scans, samples and prints 12 points on 5 inch chart paper.

Printing Rate: 5 seconds per point.

Inking: One to six colors.

Print or No-Print: Any one or any partial combination of the 12 points can be set for "no-print" and by-passed by means of 12 external toggle switches.

Scanning Selector Stepper Switch: Packaged separately from recorder, can be distantly remote at convenient location. No access required for adjustments. Thermocouple lead wires terminate at the remote selector.

Automatic Synchronization: The print wheel and remote selector are automatically synchronized. Selector switch will "home in" even after deliberate tampering with print wheel.

Accuracy: ±0.5% full span.

Minimum Span: 0-1 MV.

Range Change: Plug-in type.

Ambient Temperature Limits: 32°to 140°F.

Line Voltage Stability: Within specification for line voltage variation of ±10%.

Standardization: Zener diode reference. No batteries of any kind.

Power Input: 115 volts A.C. 60 cps. 65 watts.

Weight: Recorder 35 lbs.
Selector 5 lbs.

Dimensions: Panel space required for recorder 8-1/2 x 9-5/8.
Panel Cutout: 7-11/16 x 9-5/16.
Depth behind panel face 12-1/4.
Selector switch: 8 x 8-1/2 x 6-1/2.

FOR ADDITIONAL INFORMATION, WRITE:

westronics, INCORPORATED

3605 McCART
FORT WORTH, TEXAS

CIRCLE 50 ON READER-SERVICE CARD

CEC's 5-119 Oscillograph with 3 interchangeable magazines

Here's the universal engineering research tool that provides unprecedented versatility in monitoring high-frequency, dynamic data. CEC's 5-119 Recording Oscillograph enables engineers to use the photographic recording process best suited to their specific test requirements.

The 5-119 converts quickly to:

A DIRECT-PRINT RECORDER using an internal high-actinic light source and a 5-051 Slot-Exit Magazine that clearly resolves writing speeds in excess of 50,000 ips... produces records on standard direct-print papers without chemical processing.

AN AUTOMATIC PROCESSING RAPID-ACCESS INSTRUMENT using a 5-036B DATARITE Magazine that processes standard photographic films or papers in the shortest time of any known oscillographic process... provides ready-to-read test results in 0.8 second after exposure.

A CONVENTIONAL OSCILLOGRAPH using a 5-006A Standard Magazine and 12-inch recording films or papers that are processed following the record run.

The 5-119 provides 36 or 50 independent data input channels and wide record-speed and frequency ranges. *For complete details call your nearest CEC sales and service office, or write for Bulletin CEC 1536-X9.*

Electro Mechanical Instrument Division CEC

CONSOLIDATED ELECTRODYNAMICS *360 Sierra Madre Villa, Pasadena, California*

CIRCLE 51 ON READER-SERVICE CARD

ISSUES

The Counter Reads **00384**

and thereby registers the end of thirty-two years of *Instruments and Control System's* service to users of measurement and control devices.

editorial

YOUR editors and the entire staff of Instruments Publishing Company wish you happiness and prosperity in this New Year. More than wishing, we believe our work here is of tangible help to you in your own pursuits. Here is some of the evidence on which we base our belief, and our pride in the job we are doing.

Our circulation has grown from 19,005 to 24,500 in the past year—our renewal rate is the highest in the industry. (We also have more individual advertisers and more exclusive advertisers than any other publication in the field.)

To us the renewal rate is most significant. INSTRUMENTS AND CONTROL SYSTEMS is proud of our readers who have stayed with us for five, ten, fifteen, and some even more than thirty years.

Again, in 1960, we pledge to bring you the best and most useful information on industrial instrumentation in every issue.

Each issue will have regular features on the following:

Process Control Systems—approximately 50 working and basic process control systems will appear in this series, four or five per month.

Electronic Circuitry—approximately 50 basic electronic circuits will be described, again four or five per month.

Simulation Council Newsletter—reporting the latest simulation techniques.

Journal of SCMA—basic process and flowmetering instrumentation every month.

Digital Instrumentation—a new series.

As in the past, most of our articles will be on specific instrumentation subjects. The difference between one isolated article, no matter how good, and an integrated educational series of articles on a subject is the difference between a popular juke-box record and a symphony. We will continue to bring you symphonies of articles in the following subjects in 1960:

Temperature Instrumentation

This will begin in the January issue, but will continue in subsequent issues. It will include the following articles:

1. **Survey of Temperature Measurement Techniques** by V. G. Shaw of Shaw Instrument Company.

2. **Surface Temperature Measurement** by W. Moen of North American Aviation.

3. **Thermocouple Measurements by Use of Conventional Millivoltmeters** by Dale Kelly, San Antonio, Texas. How to read temperature by connecting a couple to an ordinary meter.

4. **Low-temperature Thermocouples** by J. F. Carlson of Hoskins Manufacturing. Covers low-temperature characteristics of chromel-alumel couples never before reported in the literature.

5. **Temperature Measurement by Thermistor.**

6. **Errors in Thermocouples** by R. J. Almond of Harco Laboratories. Calculates the maximum error that can be expected in a thermocouple circuit.

7. **The Shaw Ratio Pyrometer** by D. L. Burk of Allegheny Ludlum Steel. The conventional optical pyrometer depends on the emissivity of the radiating surface. By using the ratio between two wavelengths, the true temperature can be measured even when the emissivity is unknown.

Motion Instrumentation

The series, started in 1959, on measurement and control of displacement, velocity, acceleration, vibration and noise will continue in 1960, with special emphasis in the February issue. You will get the following articles:

1. **Survey of Acceleration Generators** by A. B. Kaufman of Litton Industries. Covers centrifuges, shakers, oscillating tables, falling weights, and pneumatic impulses.

2. **The Metrisite Displacement Transducer.**

3. **Vibration Environment Affects Instruments** by C. White of AVCO. Analysis of situations where the environment affected the instrumentation.

4. **Accelerometer Calibration** by L. Moskowitz of Schaevitz Engineering.

5. **Eliminating Vibration** by D. Franklin, Jamaica, New York.

6. **Vibration Measurement in Turbine Blades** by D. A. Morley of General Electric.

7. **Measurement of Sound and Noise** by N. Hartz of Mine Safety Appliances.

8. **Measurement of Noise at AVCO Labs** by C. White of AVCO.

9. **The Movable Core Transformer** a basic displacement transducer.

10. **Testing Aircraft Flutter Models by Accelerometers and Strain Gages** by A. D. MacLellan of Convair, San Diego.

11. **Vibration Calibration Services** of National Bureau of Standards.

12. **Measurement of Accelerometer Output** by L. Moskowitz of Schaevitz Engineering.

13. **Vibration Measurement in Bearing Manufacture** by H. R. Van Dorn of Fafnir Bearing Co.

14. **Vibration Spectrum Analysis** by E. F. Feldman, Panoramic Radio Products, Inc.

Digital and Magnetic Tape Instrumentation

Again we continue a powerful series already well underway. The articles you can look forward to beginning in March include:

1. **Time Expansion by Tape** by M. E. Anderson of Armour Research Foundation.

2. **Updating Magnetic Tape Files** by J. C. Hammerton of RCA.

3. **FM/FM Standards** of Research and Development Board, Department of Defense.

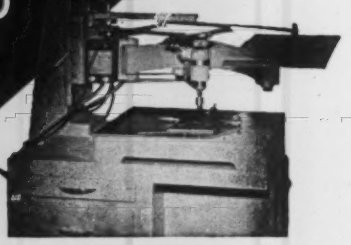
4. **FM/PM Standards** of Research and Development Board, Department of Defense.

5. **Wow and Flutter Compensation**, by R. L. Peschel of Precision Instrument Co.

6. **Advanced Decommutation Systems**, by D. F. Kahan of Telecomputing Corporation.

Continued on page 1814

GREEN PRINTED CIRCUIT DRILL



A Pneumatic Attachment on The Green Model D2 Pantograph Engraver rapidly drills holes in printed circuits by tracing templates.

- **Drill as many as 100 holes per minute. Foot switch actuates air powered operation.**
- **Drill speeds and feeds have independent adjustments. Feed regulated by air pressure.**
- **Spindle speeds up to 26,000 rpm. Permits use of carbide drills when required.**
- **D2-201 air attachment includes spindle air cylinder, regulating valve and pressure gauge, foot switch, filter and oiler, ready to operate when connected to compressor.**

The Model D2 Heavy Duty Pantograph Engraver features ratios of 2 to 1 to infinity. Unobstructed on three sides to handle large work. Micrometer adjustment for depth of cut. Vertical range 10" adjusting copy table automatically with pantograph.

GREEN INSTRUMENT CO., INC.
384 Putnam Ave. • Cambridge 39, Mass.

FOR FULL DETAILS, WRITE, WIRE OR CALL

CIRCLE 52 ON READER-SERVICE CARD

7. **Advanced Tape Instrumentation Systems.**
8. **Boolean Algebra** (4 articles) by G. A. Wires of Packard-Bell.

Further, this subject has become so important that we will devote a section of INSTRUMENTS AND CONTROL SYSTEMS to digital instrumentation each month. Look for it.

Electrical Measurements and Standards

All readers are familiar with our famous coverage of this field. We will continue the subject in the April issue with the following, all of basic importance to every man concerned with measurements:

1. **Measurement of Electrical Conductivity** by L. Cuniff of Industrial Instruments.
2. **Special Bridges**—limit proportional, percentage, etc.
3. **The Kelvin-Varley Voltage Divider** by J. B. Kelley, Physics Research.
4. **Magnetic Measurements.**
5. **Use of Kelvin Bridge** by Gray Instrument Company.
6. **Industry Calibration Survey.**
7. **National Standards for Electrical Measurement** by F. B. Silsbee of National Bureau of Standards.
8. **Calibration Instrumentation** by S. J. Zammataro of Bell Telephone labs.
9. **NBS Resistance and EMF Calibration** Services.
10. **Shift to the Metric System?**
11. **Reference and Working Electrical Standards** by F. B. Silsbee of National Bureau of Standards.
12. **Universal Constants as Standards of Measurement.**
13. **Equipment at the Western Electric Standards Laboratory.**

For the balance of the year you can look forward to the latest information:

May issue—Thermometry
June issue—Flow Measurement and Control
July issue—Analytical Instrumentation
August issue—Programming and Time Instrumentation
September issue—Analog Computer Instrumentation
October issue—Recording Instrumentation
November issue—Speed Measurement and Control
December issue—Pressure and Vacuum Instrumentation

A Superior Detector for Infra-Red Spectroscopy

GOLAY PNEUMATIC DETECTOR*

Among the characteristics that render the Golay Detector superior to other types of detectors for use in infra-red spectroscopy are:

1. **An effective sensitive area 3/32" in diameter.**
2. **Sensitivity of 6 x 10^{-11} watts RMS-ENI when used with "chopped beam" method and with recording time constant of 1.6 second.**
3. **Uniform sensitivity from the ultra-violet through the visible and the entire infra-red, and up to the microwave region.**
4. **Improved, drift-free. A. C. operated amplifier with step gain controls and four response periods.**

Write for EPLAB Bulletin No. 10

*Fundamental and experimental aspects of this detector are discussed in the following publications: Rev. Sci. Inst. *18*, 347 and 357 ('47); ibid. *20*, 816 ('49); Proc. IRE *40*, 1161 ('52).

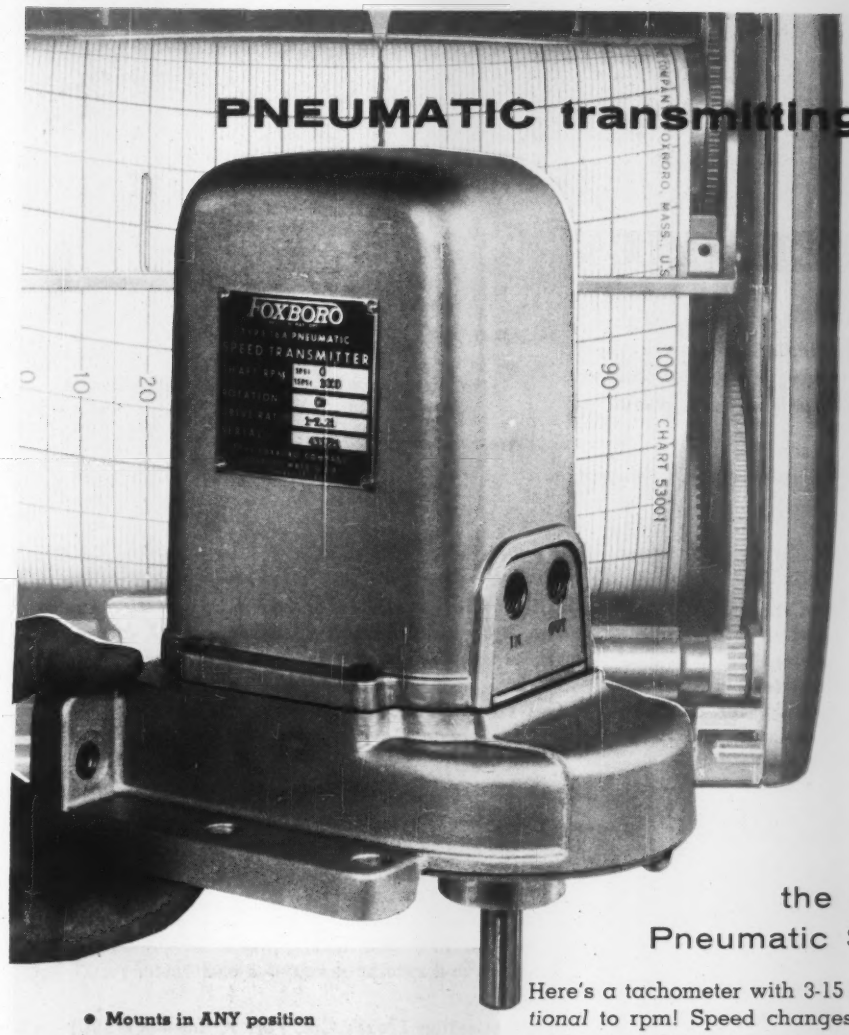
278-8

THE EPPLEY LABORATORY, INC.
SCIENTIFIC INSTRUMENTS
2 Sheffield Ave. • Newport • Rhode Island • U.S.A.

CIRCLE 53 ON READER-SERVICE CARD

PNEUMATIC transmitting tachometer with

DIRECT LINEAR SIGNAL

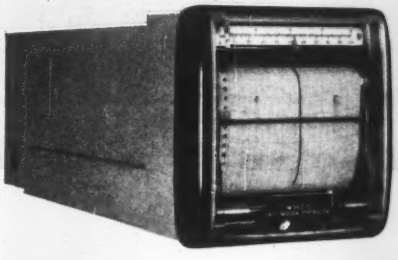


the Foxboro Type 16A Pneumatic Speed Transmitter

- **Mounts in ANY position**
- **Accurate to ±½% across entire range**
- **Needs no lubrication**
- **Dust-tight gasketed case continuously purged**
- **Simple force-balance mechanical principle.**

Direct-connects to remote pneumatic recorder or controller, such as Consotrol panel recorder shown below.*

**Reg. U.S. Pat. Off.*



Here's a tachometer with 3-15 psi air signal *directly proportional* to rpm! Speed changes are recorded on a uniform-scale chart. Accurate measurements of rpm are easy to read throughout the entire range. No crowded bottom scale!

The Type 16A Speed Transmitter will measure *any* desired range. (An optional integral speed changer is available for ranges from 0-600 rpm to 0-6500 rpm). Full-scale accuracy of ±½% is consistently maintained. Small and light weight, it can be mounted *in any position* — never needs lubrication.

For rotating equipment having wide speed variations, the Type 16A is ideal. It's available for either clockwise or counter-clockwise rotation, and can easily be incorporated into any present pneumatic control system. Write for full details. **The Foxboro Company, 4612 Neponset Ave., Foxboro, Massachusetts, U.S.A.**

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PNEUMATIC SPEED TRANSMITTERS

CIRCLE 54 ON READER-SERVICE CARD

COMPUTER USES

Computer control is indicated wherever there exist many variables, many process objectives, and complex relationships between variables and objectives.

Electric Power Station (Little Gypsy Station—Daystrom)

Control start-up and shut-down of station. Approximately 800 steps are involved in start-up or shut-down.

Monitor a large number of selected input signals continuously, and formulate alternative routes.

Procedures for hot or cold start-up, for complete shut-down, and for temporary shut-down and banking the boiler will be provided.

Runs plant, operating major control loops—(1) combustion control, (2) steam temperature control, (3) feedwater control, and (4) spray control (overriding steam temperature control—a safety feature).

Includes a fuel safety and purge system. Upon indication of explosive mixture in boiler, gas is shut off instantaneously and boiler is purged with air. Shutdown procedures are instigated immediately.

Computer scans all inputs for off-limit operation and computes hourly computations of component efficiencies and over-all efficiency.

Electric Power Generation (Sterlington Station—Daystrom)

In addition to scanning 216 variables (fuels, flows, bearing temperatures, electric variables, steam variables, etc.), an hourly heat rate is computed.

Electric Generating Station (Huntington Beach—GE)

Scan 900 points, log 50 critical quantities each hour, and identify and print out information from more than 300 alarm points.

Complete automatic hot and cold starting, normal and emergency shutdown, and continuous control of the boiler-turbine-generator systems.

Corrective action for abnormal conditions detected during on-line operation of the system are initiated automatically.

Card-Programmed Rolling Mill (Allegheny Ludlum Steel—GE)

Controls reversing roughing mill by programming drive direction and speed, drive screwdown, edge speed, edge opening, approach table and sprays.

Natural Gas Liquids Cracking (Phillips Chemical—Autonetics)

Scan and log variables and compute operating guides (furnace conditions and yields). Closed-loop control via set-point adjustment is planned for later.

Gas Dispatch (Public Service Co. of Colorado—Libratrol)

The Gas Dispatcher is interested in two numbers—total flow for an hour for demand control, and total flow for 24 hours for buying on basis of total volume of gas.

The cost of gas is computed on a two-part rate—commodity component and demand component. The computer computes both demand and total flow using data from 35 orifice meters, plus static pressure, temperature, and specific gravity for each meter run.

Polymerization (Texas Co., Port Arthur—RW300)

A polymerization unit takes a mixture of various gases, primarily propylene, ethylene, and propane, and hooks molecules of propylene together under high pressure and temperature control in the presence of a catalyst to turn them into high-test gasoline blending stock.

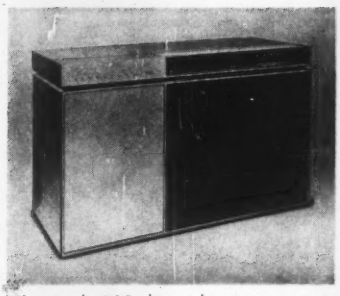
The computer input (analyzed incoming gases, pressures, flow, and temperatures) are used to make a judgment in the light of a mathematical model for maximum efficiency at the moment; the computer resets the plant's control to conform to this judgment every 5 minutes.

Cement Manufacture (Riverside Cement—RW300)

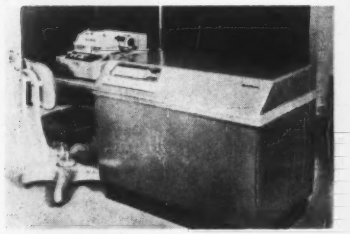
Amount, chemical composition, and point of origin of rock and other raw material for blending in proper proportion for cement-making. Factors include hauling distances and cost of quarrying in various areas.

Catalytic Cracker (Esso, Baton Rouge—L&N)

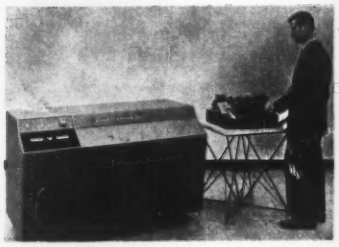
On-line computation of 27 operating guides, involving 160 inputs. Periodic logging of average values; on-demand logging of instantaneous values;



Libratrol 500 has drum memory.



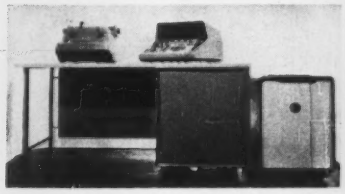
Royal Precision LGP-30 has drum memory.



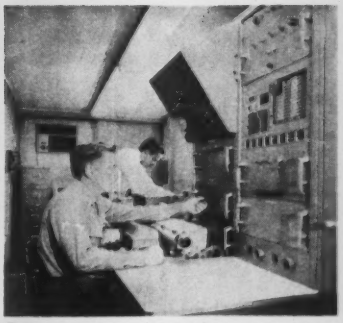
RW300 has drum memory.

Bailey Power Demand Computer has core logic units.

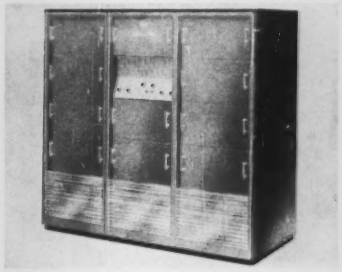
General Electric 312 has drum memory.



Autonetics Recomp has disc memory.



Daystrom computer uses core memory.



Foxboro-RCA 110 system uses core and drum storages.

Bendix G15 has DDA accessory.

or operating guides; log of daily summary. Inputs include 160 variables—pressures, temperatures, flow, gas analysis, etc.

Catalytic Reforming Pilot Plant (Esso—CEC—LGP30)

Control loops include pre-heater temperature, reactor temperature, system pressure, stabilizer condenser temperature, stabilizer reboiler temperature, gas feed rate, recycle flow rate, oxygen blending. These loops are closed with set points under control of the computer except for stabilizer temperatures and liquid-level controller (set manually).

Computer perform averaging and material-balance computations during reading cycle. It surveys limits of operation for given conditions and schedules optimization programs based on chemical composition. It controls the set points of the control system.

Power Demand Computer (Union Carbide Nuclear—Bailey Metrotype)

Computing functions with magnetic drum or magnetic-core memory can be added to the Bailey Metrotype system. One installation involving a computer is the Power Demand Computer furnished to Union Carbide Nuclear Co., Paducah, Ky. It indicates total predicted power consumption through 17 circuits for ½ hour periods. A new prediction is made each 5 minutes based on the rate of consumption for the past five minutes plus actual power consumed in each previous 5-minute period. The Power Demand Predicter computer is solid state, with magnetic-core logic units. No control functions are incorporated.

Electric Power Generation (West Penn—Royal McBee)

Solves load flows in networks up to 100 busses and 270 lines; computes operating guides.

Electric Power Generation (Philadelphia Electric—Minneapolis-Honeywell)

Will scan and log in excess of 4000 variables. Computer performs economic dispatch of electric power and (time shares) billing computations. Computes operating guides and has variables under control of the computer for load-frequency control.

Continued next month

CRESCENT ARMORED MULTITUBE®

IMPROVED CABLED TUBING

gives you a better job at less cost

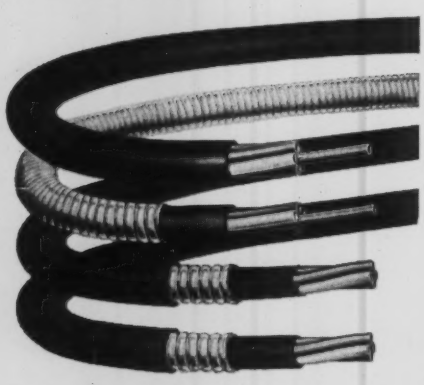
Carries Air, Gas or Fluid

CRESCENT ARMORED MULTITUBE is a group of 2 to 37 tubes of copper, aluminum, steel or polyethylene **spirally cabled together** and protected by a flexible, interlocked galvanized steel armor, or by a tough corrosion resistant thermoplastic sheath, or a combination of both (see below).

The SPIRAL CABLING of the tubes permits easy bending to a small radius without distortion of the tubes. It can be installed with great saving in time.

Special constructions are available for underground runs. This product is licensed under U. S. Patent 2,578,280.

CRESCENT ARMORED MULTITUBE completely out-dates the old method of using single tubes, with users reporting *savings in installed cost of* from two to five times the cost of the multitube. In addition, the MULTITUBE system will result in fewer connections and fittings, lower costs for supports or racks, ease of mounting and less space.



FOUR CORROSION-RESISTANT TYPES

A plastic jacket of polyvinyl chloride over SPIRALLY CABLED copper or aluminum instrument tubing provides complete moisture and corrosion protection for the tubes. Flexible galvanized steel armor in various combinations, as shown, gives maximum protection for permanence. Available in size ¼" O.D. in lengths to 1000 feet in from 2 to 37 tubes.

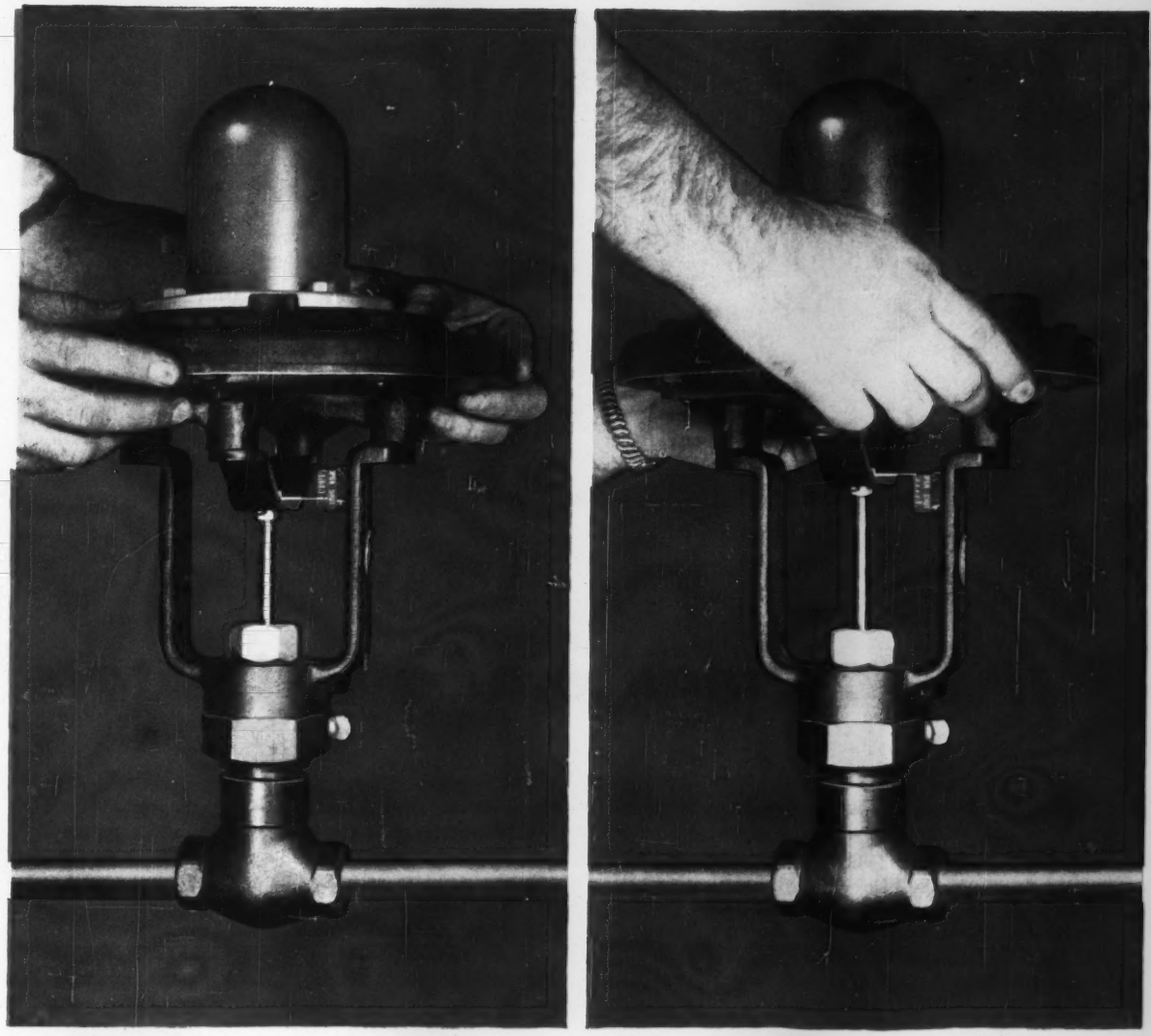
Plastic Coated Single Tubes, copper or aluminum, should be used to give corrosion protection to all single lines up to the final tube fitting, where trouble from corrosion may occur.

SEND FOR BULLETIN 458-A GIVING COMPLETE INFORMATION AND ENGINEERING DATA

CRESCENT INSULATED WIRE & CABLE CO.

Trenton 5, New Jersey

CIRCLE 56 ON READER-SERVICE CARD



LOOK HOW EASY IT IS TO REVERSE THE ACTION OF A FOXBORO CONTROL VALVE!

air-to-open . . . air-to-close — one valve for the job of two

Unbolt the motor casing and rotate it 90°; rebolt and shift air connections — that's all you do to reverse the operation of a Foxboro control valve. Takes just a few minutes — without touching valve body or process piping — without employing special tools or skills.

Foxboro reversible motors are especially suited for needle valves, Saunders-type valves, and other control valves having non-reversible bodies. They're also used with Foxboro Stabilflo* Valves — the original valves with equal percentage flow characteristics and wide 50 to 1 rangeability.

Foxboro control valves with their quick-reversible valve motor, are an exclusive Foxboro development. They're perfect for pilot plant operations and other processes frequently "juggled." Types and materials to meet any process requirement.

Write for detailed bulletins today. **The Foxboro Company, 1412 Norfolk Street, Foxboro, Mass.** Reg. U.S. Pat. Off.

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CIRCLE 55 ON READER-SERVICE CARD

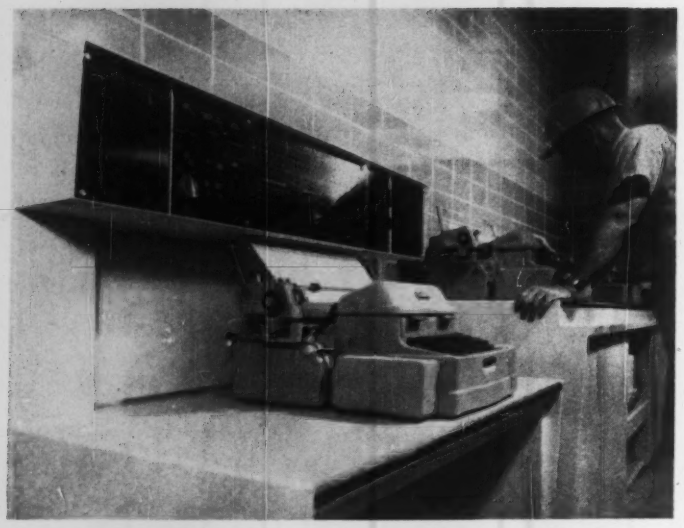


FIG. 1. CONSOLE installed at Sterlington.

JOSEPH A. REINE, JR.
Louisiana Power & Light Co.

Performance of a Solid-State

LOUISIANA Power & Light Company is proud to be one of the first to use a digital computer on-line in a power plant. The computer system, installed on units 5 and 6 at our Sterlington Station, continuously monitors 216 analog variables for off-normal conditions, integrates and averages 23 variables, logs 100 variables hourly and 23 variables daily, computes net plant heat rate hourly, and produces any of this information upon demand.

Another first at Sterlington is the use of Westinghouse "Cypak" magnetic amplifiers for our boiler protection on both our #9 and #10 boilers. This installation performs all the functions necessary to protect a boiler rated at 1,500,000 lb of steam per hour at 1800 psi at the throttle and 1005°F superheat and reheat. Included is purge permissive circuitry. The complete Cypak installation is housed in a metal outdoor housing approximately 4′ x 4′ x ¾′ in size.

The computer, or as we prefer to call it, the Operational Information System, comprises:

a. **Input devices**—thermal converters, transducers, pulse counters, thermocouples and other devices to produce at the computer input terminals not over a forty-millivolt analog input.

b. **Mutiplexing section**—350 mercury wetted relays providing random access for each measured variable, and solid-state matrices for addressing, together with solid-state drivers. Computer programming determines pattern of selection.

c. **Analog to digital converter**—the *DADIT* (Daystrom Analog-Digital Integrating Translator).

d. **Power supplies** for both memory and computer.

e. **Memory section**—2048-word ferrite iron-core memory, random access.

f. **Computer section**

g. **Input section**—console and typewriter.

h. **Output section**—two logging typewriters, one for each unit, an alarm printer, and a Panalarm annunciator system. The logging typewriters are driven by a tape which has been punched by a Teletype Corporation high-speed punch, and then passed through a tape reader.

Equipment Performance to Date

The Operational Information System arrived at Sterlington via cross-country van lines in March 1958, from Daystrom Systems, LaJolla, California. After preliminary checks were made to determine if any damage was done to the equipment during shipment, it was put into service.

Progress was being made at a rapid pace a few months later. The machine had been on the line and quite a few of the vital inputs were connected. These consisted primarily of thermocouples and thermal converters. Then—catastrophe struck. Somehow 120 vac was impressed on input pair 416-417 which is the lockout circuit for the Air Heater 6B.

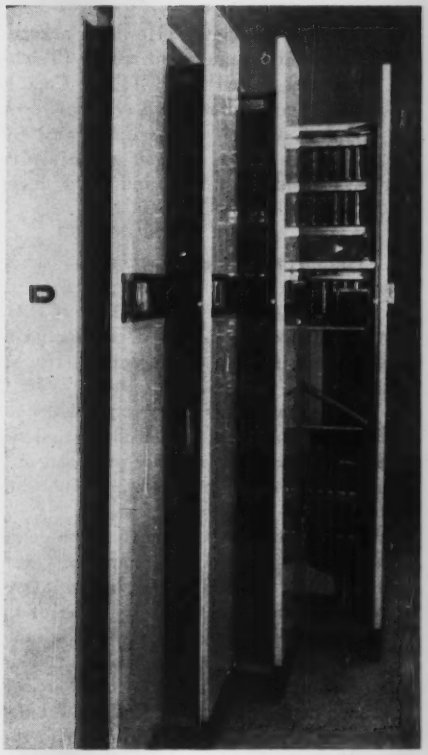
The damage to the Data Logger was as follows:

a. Burned out that particular Panalarm relay driver circuit.

b. Burned out 100-kilocycle clock, including sev-

Presented at Solid State Electronics Symposium, Philadelphia, Nov. 23-24, Philadelphia Section, ISA.

A factual performance record of a pioneering installation featuring a solid-state logger computer, the Louisiana Power & Light Co., Sterlington, La.



Process Computer

veral transistors.

c. Burned out three precision resistors in the DADIT.

d. Caused parity errors to develop in approximately twelve memory cells.

To prevent this trouble arising again, the manufacturers developed an isolated input device. This device consists of mercury wetted relays that are being driven by a contact closure of the pieces of equipment being locked out, and in turn these relay contacts lock out the operational systems.

Several weeks later the computer power supply failed, bringing the machine to a halt. As there were no manufacturer's engineers at Sterlington we at the plant began to run the trouble down. We knew which unit of the power supply was in trouble since the fuse was blown. Checking with a voltohmmeter we found two bad zener diodes. The damaged diodes were replaced and the equipment restored to service.

These were not the only zener diodes found bad. After trouble developed in two DADITs because of defective zener diodes, it was concluded by the manufacturer that a bad shipment of diodes must have been received from the diode manufacturer since all the defective diodes were purchased on the same order.

All zener diodes in the system were replaced by the manufacturer and there have been no further problems.

The manufacturer guarantees 99% operational availability of the computer system, performance to be demonstrated over a six-month test period. The official test commenced July 1, 1959, and the results thus far are as follows (*note—nothing solid-state has failed*):

1) The punched tape feeding into the off-line tape reader jammed, fouling one hourly log cycle. Tape was straightened and rerun in order to retype the hourly log.

2) False alarms appeared the first week of the run. This was traced to a synchronizing problem between the DADIT and the computer, which was corrected by installing a synchronizing flip-flop. This synchronizing problem had been experienced earlier in the field and was then corrected by field modifications. Just prior to this test run, the manufacturer installed a modified DADIT, including these modifications, but due to an engineering oversight, the synchronizing flip-flop had not been included in the modified equipment.

3) On one occasion, a single wheel was found spinning on the alarm printer. The trouble was located in the millisec relay associated with the wheel locking pawl solenoid. The manufacturer has recently developed sufficiently high-powered circuitry for direct operation of the solenoids, eliminating the millisec relay. This modification will be made at the termination of the six months test run.

Spare Parts

The spare parts kept on hand at Sterlington are as follows:

Analog-Digital Converter (DADIT)
Complete set of power supplies

Off-normal Printer (Hewlett-Packard Co.)

Output tape punch and reader (Teletype Corp.)

Mercury wetted relays (Clare Co.) are used in the input matrix and assorted types of these are kept.

Several of each of the driver units, flip-flops, etc., are kept as spares as well as an assortment of resistors, transistors, diodes and other devices.

Maintenance

To this date the only repairs that company personnel have performed are on the punch, printer and minor repairs on the typewriters. This is where most of the maintenance has occurred. The actual computer component failures, as mentioned, have been at a minimum.

Maintenance has been simplified by use of roll out cabinets, taper pin connectors, male-female plug arrangements, etc. The taper pin connector simplifies removal of the computer components from the roll out cabinets.

Thousands of these impact-type gold taper pin connectors are used in the computer. One particular case of trouble that occurred shortly after the computer was put into service was that one of these connectors had not been impacted into its mating connector. Intermittent connection resulted, which caused a large number of false alarms. The cold-junction reference compensation was affected, causing high negative temperatures to be indicated in the thermocouple inputs. This trouble developed in July 1958 but, to my knowledge, there has been no repetition.

One of our major input problems has been the accurate counting of megawatt hours into the data collector. The watt hour meters incorporate brush contacts and a rotating commutator which energize the amplifying relays. The relay burden proved too great for the brush-commutator design and burning resulted. Corrective steps taken to eliminate this were:

1. Silver plate the contacts and commutator.
2. Install current-limiting resistors in the coil circuit of the relay amplifiers.
3. Install a capacitance-resistance network across the contacts.

These steps reduced the burning, but did not stop it.

About three months ago a trial megawatt-hour meter was received from Ebasco Services, the Consulting Engineers who do the consulting work for Louisiana Power & Light Company. This was a conventional megawatt-hour meter, but attached to it was an impulse device for counting the megawatt hours. This has proved to be the most reliable megawatt-hour counter we have used to date.

Training of Maintenance Personnel

Since the Operational Information System has been at Sterlington, personnel of Louisiana Power & Light Company have worked with the manufacturers's engineers, getting familiar with the physical equipment, and also doing minor trouble shooting. Every problem that was encountered by the project engineers was explained. In addition to myself, several electricians and several instrument men were trained in calibration of input devices and maintenance of output equipment such as alarm printers, punches, readers, typewriters, etc.

Since the 6-month trial period began on this equipment, a manufacturer's engineer has been on duty continuously at Sterlington. With the consent of the Plant Superintendent a 4-hour weekly class was started to indoctrinate as many plant personnel as possible on the use of the equipment, its operation and the mathematics used by the computer. The manufacturer also plans to conduct a 6-10-week training program at their plant for selected plant personnel on programming the computer maintenance.

None of the maintenance personnel are computer specialists. It is the manufacturer's and Louisiana Power & Light Company's thinking that the trouble will not be so great that these men will not be able to handle it. If trouble reaches a point where outside help is needed, Daystrom will be contacted and engineering specialists provided.

Trouble Shooting

As mentioned earlier the roll out racks, taper pin connectors, and plug in connectors for different units make for ease of maintenance.

However, the taper pins are so close together that the maintenance man can easily get an oscilloscope probe across them, thereby damaging the computer. This has occurred. It could be corrected by use of a different type of probe, now being designed.

We use the Tektronix P510A Attenuator Probe with input impedance of 10 megohms paralleled by 14 $\mu\mu$f. The oscilloscope used for maintenance is the Tektronix Type 535.

Summary and Conclusion

How can we, a fairly small utility, afford such a large Operational Information System? It is hard to justify from a purely economic viewpoint, but from knowledge gained to further the advancement of this field it has proven invaluable.

Now, *after sixteen months of operation* the solid-state digital computer seems to be the equipment needed for supplying the decision-making ability in a fully automatic power plant. The Louisiana Power and Light Company, Ebasco Services and Daystrom Systems are so convinced of the reliability of this equipment that they are now in the process of building and putting into service a 230-megawatt unit at the Little Gypsy plant, completely controlled by a solid-state computer.

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3. Don Aswell and George Parmakian, "An Operating Report of the Monitored Sterlington Station," American Power Conference 21st Annual Meeting Chicago, Illinois, March 31, April 1 and 2, 1959.

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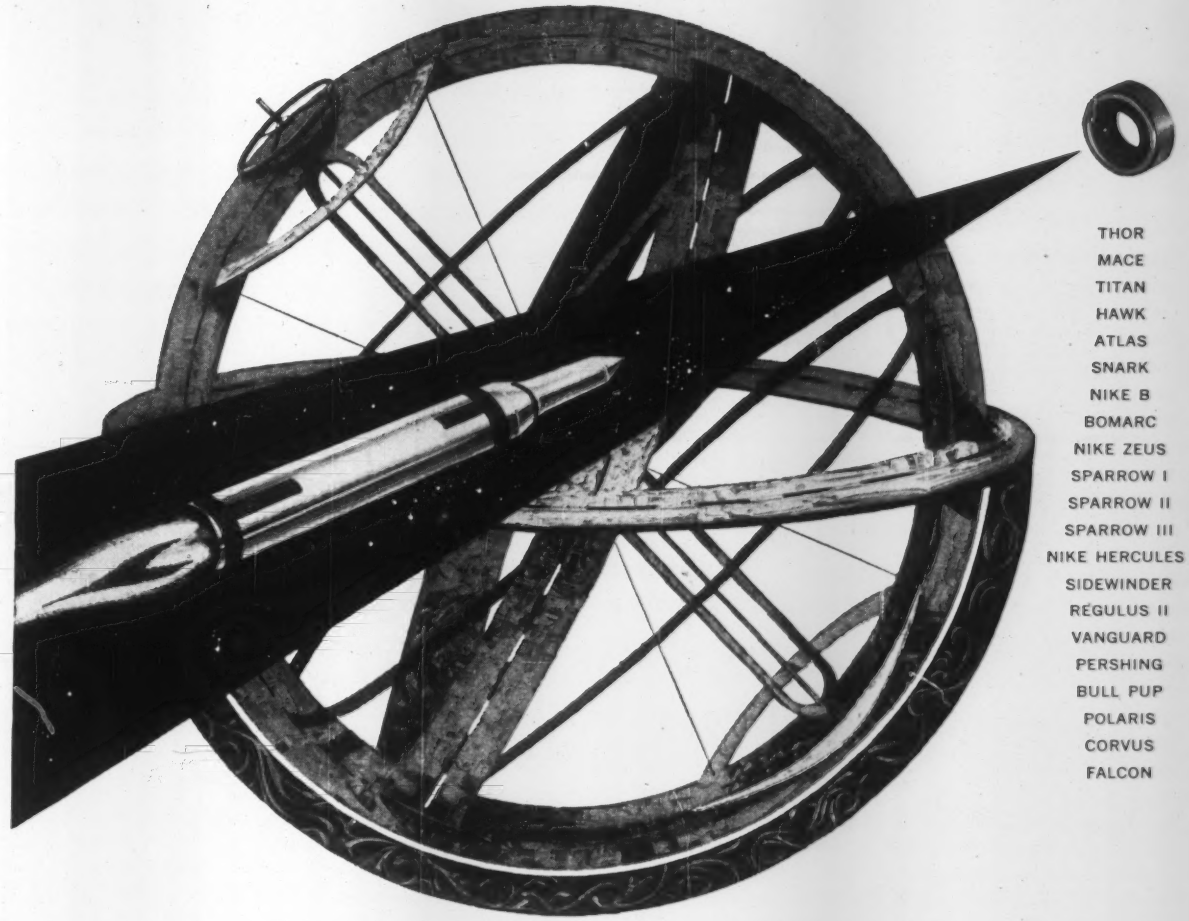

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ND Adds New Dimensions To High Speed Gyro Rotor Bearings!

At speeds up to 24,000 RPM precision rotor bearings in inertial guidance and navigational systems are highly critical components. Early research and development in design and manufacturing at New Departure is solving the problem and thus winning vital roles for N.D. integral rotor bearings in missile projects. For example, "B" Series bearings with separable inner ring developed by N.D. are helping set performance records in such inertial guidance systems as the AChiever.

New Departure is also supplying high-precision rotor bearings for the inertial guidance system in Polaris.

These bearings, through advanced manufacturing techniques, exacting inspections and controlled environmental tests, backed by 50 years of laboratory testing experience, give precision and uniformity far above the most precise industry standards. They promise new performance and *reliability* for the submarine-launched IRBM.

You can look to improved *performance* and *reliability* when you include an N.D. Miniature/Instrument Bearing *Specialist* in early design level discussions. Call or write Department L.S., New Departure Division, General Motors Corporation, Bristol, Connecticut.

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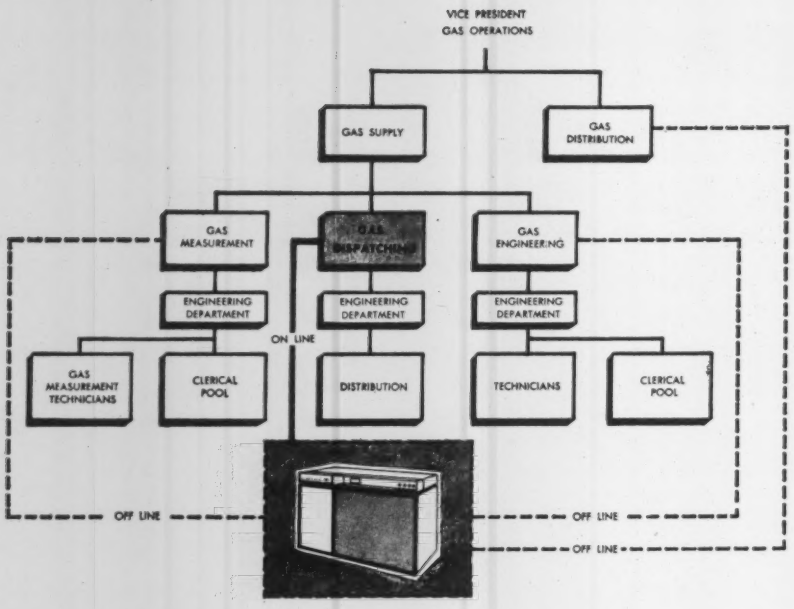

FIG. 1. LIBRATROL 500 will perform both off-line and on-line functions.

BILL KARCHER
Public Service Company

NATURAL-GAS-

NATURAL GAS distribution system for the Public Service Company of Colorado system consists of 16 metering stations which may contain several orifice-type meters for *gas flow measurements*. Twelve stations are metered for *purchasing*, 3 stations measure *gas consumed for steam generation*, and 1 station is metered for *sale of gas*.

The cost of gas is computed on a two-part rate. The two portions of the rate are the commodity component and the demand component. Each cubic foot of gas carries the commodity rate. The demand component is based on the maximum flow rate for a one-hour time period established during any one day in a year and is then applied over the next eleven months.

Public Service Company controls the system peak by monitoring the demand on a twenty-four hour basis throughout the year, and by interrupting service to certain industrial customers if the demand to the area approaches the pre-established peak.

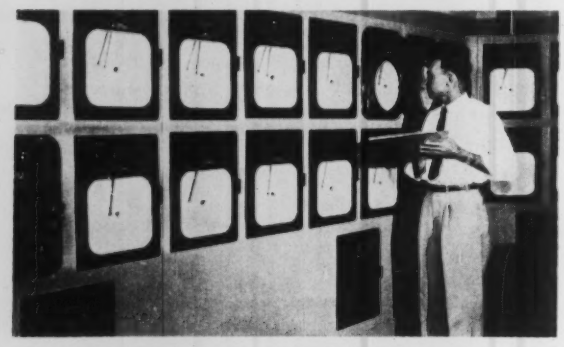

FIG. 2. DATA IS received by Bristol Metameters and phone.

Gas Distribution System

The sixteen metering stations contain a total of 35 meter runs. Thirty of these meter runs have orifice plates, and five runs consist of pipe parallel to the orifice and calibrated with respect to the orifice, but not continuously measured.

The basic dynamic data required to calculate flow by means of orifice-type meters are differential pressure, static pressure, temperature, and specific gravity for each meter run. This data is received in the Denver computer room by Bristol Metameters and phone (Fig. 2).

Instantaneous flow through an orifice meter is calculated by:

$$Q_h = C' h_w P_f$$

Head (h_w) and absolute static pressure (P_f) are received in the computer room from telemeter equipment, and the variable constant (C') is evaluated.

The gas dispatcher is interested in two numbers, both of which are total flows for different periods of time:

1. Total flow for an hour, or other arbitrary time period, for demand control.
2. Total flow for 24 hours, or other arbitrary time period, for buying on basis of total volume of gas.

Both of these numbers are cubic feet of gas (V) and are the area under the curve of Q vs time.

The number and complexity of the manual calculations involved require from 30 to 45 minutes of each

HUGH JACOBSON
Librascope, Inc.

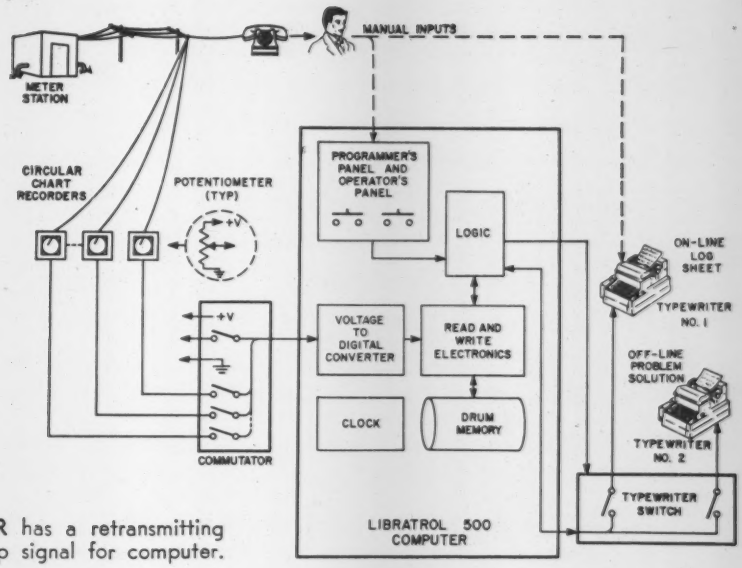

FIG. 3. EACH RECORDER has a retransmitting slidewire, which will develop signal for computer.

DISPATCHING COMPUTER

hour's time. This is an extreme burden on the dispatcher, who also must devote a portion of his time to making decisions which will control the demand and maintain adequate gas supplies in the system.

The computer system will type out total hourly gas flow and 24-hour total gas flow for each of the 16 meter stations. It will also type out combinations of this data. The computer calculates every 0.1 hour (6 minutes); the computation requires only 55 seconds. The circular-chart recorders have a 15- second period, and therefore will be the limiting factor if 4 or more recorders share a common transmission line.

The required computation is programmed for computer solution of V at a six-minute interval and also to sum V for the time period of interest, hourly and daily. The equation shown is a conventional form for computer computation of flow rate and numerical integration to obtain total volume:

$$Q = F_b F_{pb} F_g \left[1 + \left(0.68462 - 0.26923 \frac{d^4}{D^4}\right) \frac{h}{27.7P}\right] \left[\sqrt{hp + b'}\right] \times \sqrt{\frac{(ap^2 + bp + c - 1)\left(\frac{520}{460 + T}\right)^{2.9125} + \left(\frac{520}{460 + T}\right)}{1 + \frac{h}{27.7P}}}$$

As less than one minute is required to do a calculation every six minutes, approximately five minutes of computer time is available for other calculations. This time is used to perform *off-line calculations.*

Each recording element is equipped with a retransmitting potentiometer; fifty-five potentiometer kits will be initially installed in this system. A 20-v power supply is provided for excitation voltage, and the output signal from the potentiometer wiper is proportional to the pen displacement, which in turn is proportional to the telemetered signal (differential pressure, static pressure, or temperature). A block diagram of the complete system is shown in Fig. 3.

The potentiometer voltage will be switched sequentially to the voltage-to-digital converter by the commutator. The commutator is constructed of mercury-wetted contact relays and is effectively a single-pole, 72-throw relay. The input rate is 75 channels per second.

The voltage-to-digital converter is an electronic, successive-approximation type. The output is to ± 1024 bits and accuracy is $\pm 0.1\%$ of full scale. The output is a straight binary value and the visual readout is octal code.

The programmer's panel contains the manual control functions for a programmer to initially enter a program into the computer or to modify a program in any desired manner.

The operator's panel contains power on and off switches, start computer switch, and five unconditional transfer switches. The unconditional transfer switches will cause a program transfer to a specified location if actuated. These switches then may be used to indicate system conditions such as "parallel meter runs are open," or may be used to insert constants on new data into memory under program control.

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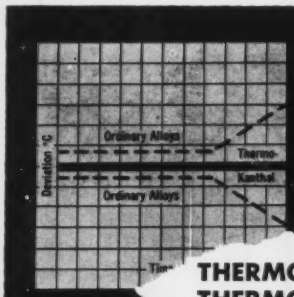

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Digital Control Computers

GERHARD L. HOLLANDER
Philco Corp.

After a review of the fundamental requirements of an on-line real-time control computer, the airborne Transac C-1100 computer is described.

THE COMPUTER in the feedback system has been called an *on-line, real-time control computer*. What do these terms denote, and how do such computers differ from others?

On-Line Device: The device accepts information from the process as it is generated with negligible delay.

Real-Time Computer: This computer processes data at the same speed at which the process operates.

Control Computer: The output of this computer actually controls the process.

On-line computers generally preclude the intervention of a human being, because these computers must take the data from the process as fast as they are generated. Control computers are not the only on-line devices; others are the data-logging and data-reduction systems which accumulate data from processes under test and present the information for later examination.

Real-time computers operate at the same speed as the process. Obviously a control computer must be a real-time computer in order to control the process. Simulators are also real-time computers although they are not tied to the process at all. Real-time computation is not necessarily faster computation; for example, some analog computers do not qualify as real-time computers because they operate many times faster than the actual process.

On-Line Computers

The two primary requirements of on-line computers are: (1) the ability to communicate with the rest of the system, and (2) the ability to accept data with negligible delay.

To communicate with the system or process, the computer needs translating equipment to speak its language. When the computer is far away from the system the language must often be translated twice—once for economical transmission and once again for matching to the system. In an on-line system, the transmission cost often exceeds the rest of the costs.

The control computer is a nonlinear, sampled element in a feedback-control system. Since a computer can not only calculate quickly but also make a vast variety of logical decisions, the action of the controller in the feedback control system can be almost as complex as desired.

Figures of Merit

The requirements for a computer in a digital control system are specified by four figures of merit—precision, processing rate, delay time, and versatility.

Precision is specified by the number of binary or decimal digits in the basic computations. For occasional use, more than the basic precision can be obtained by programming the computer for multiple precision. This produces the economic advantage of full utilization of the basic precision, instead of complicating the computer by designing it for a peak precision which is only used occasionally.

Processing rate measures how many computations the computer can carry out in a given time; *delay time* measures how long it takes for an input to be reflected in an output. Notice that processing rate measures different characteristics from delay time[2]. For example, a computer can handle 60,000 additions per second, but may delay every answer 5 seconds. In a data-reduction system only the processing rate, not the delay time, is important—but in a control computer, both are significant.

Versatility or flexibility of the computer is measured by the variety of tasks it can perform. Normally, these are relative measures, as no absolute measures have been established. The more versatile the computer, the more complex its control section and, therefore, the more equipment is needed.

In a feedback loop, the computer must be very fast, with delay times measured in milliseconds. Basic pre-

TABLE 1—CHARACTERISTICS OF A TYPICAL C-1100 COMPUTER

Precision	20 binary digits (one part in 10^6)
Typical Arithmetic Speeds (including memory access)	
Addition	15 Microseconds
Subtraction	15 Microseconds
Multiplication	60 Microseconds
Division	60 Microseconds
Square-root	60 Microseconds
Memory Capacity	
Cores	64 words
Drum	2200 words

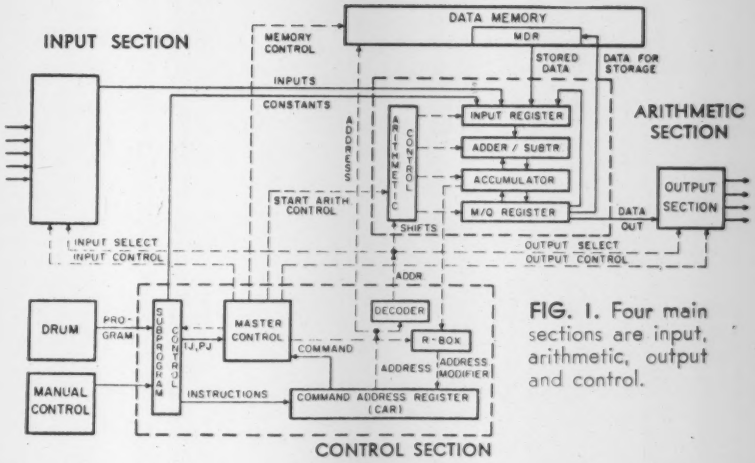

FIG. 1. Four main sections are input, arithmetic, output and control.

cisions in the order of one part in 10,000 are ample. While control computers are much more complex than conventional controllers, they are generally less flexible than scientific computers, because control computers are usually designed for a limited class of applications.

Airborne Computers

The airborne computer must reliably perform many jobs under adverse environmental conditions with minimum weight. These computers always operate in real-time, and most of their tasks are control operations. Therefore, airborne computers must not only have all the attributes of control computers, but they must also have utmost reliability; human life depends on the proper functioning of an airborne computer.

The Transac C-1100

The Transac* C-1100 computer has been designed to meet the requirements of an airborne computer[3]. Its characteristics include (1) transistorization for reliability and light weight, (2) general-purpose stored-program organization for versatility, (3) parallel organization for fast operation, (4) provisions for operator and process control decisions for easy sharing and automatic adaptation.

Typical precision, speed and many memory values are summarized in Table 1.

The C-1100 computer consist of the four main functional sections shown in Fig. 1. The *arithmetic section* performs all arithmetic and decision operations. The data memory stores "scratch-pad" (intermediate) data that vary during operation. The *input* and *output sections*, which differ from one application to another, select one from a multiplicity of inputs and direct the result to one of a multiplicity of outputs in any arbitrary code. The entire operation of the computer is coordinated by the *control section*, which receives its instructions from either the drum or the manual control. The drum is generally preprogrammed; after the program has been written, all provisions for altering it are removed to prevent accidental changes during operation. Manual controls are primarily for operator supervision and mode selection.

Since a drum can store more information per unit volume than cores, the bulk of the instructions, programs as well as constants, are on the drum. Typical drums in the C-1100 series store 2,000 to 5,000 words; typical core memories, 64 to 256 words.

Applications

Typical computations for the control of a new jet airliner might be: (1) *Air Data* wherein true airspeed and altitude are computed from temperature and pressure measurements, (2) *navigation*, including present-position course computations, (3) *cruise control*, computing economical altitude, (4) *landing* with radio aids, (5) *control* of aircraft (autopilot), (6) *displays* —in a recent development, dials were replaced by cathode-ray image of an idealized earth surface with a superimposed ribbon representing the prescribed flight path, (7) *engine* performance check and monitoring, (8) *diagnostic* checks.

Most computations are more complex than they appear offhand, because the program must provide for exceptional conditions which may occasionally occur. The length of a typical navigation problem having 200 basic program steps can be more than doubled by housekeeping functions and such exceptions.

Despite complications, all these computations can be handled by a single high-speed digital airborne computer like one of the Transac C-1100 series, which occupies from one to three cubic feet and weighs between 50 and 150 pounds.

*Registered trademark Philco Corporation

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Computer Control Philosophy

CLIFFORD E. MATHEWSON

Daystrom Systems

COMPUTER Data Reduction and Control means different things to different people. New technologies are often hampered by terminology and semantic problems; the concept of the on-line process computer system has fared worse than most.

Trade journal articles have contributed to the confusion. Much of the general misunderstanding appears to be caused by the extremely broad use of the term "computer control," which has been used to cover equipment and projects varying in size from one to thousands of inputs.

The data logger, which preceded the general-purpose digital computer, has as its primary function the automatic tabulation of process data on log sheets. It usually performs various mathematical operations—scaling, linearization and square-root extraction. As system sophistication increases, other functions such as integration, division and multiplication must be added. It is at this point that the special-purpose data-logging system becomes sufficiently complex that the general-purpose digital-computer system becomes competitive.

The on-line process digital computer differs from the logger in these respects—(1) it has a memory device which can be used for programming the computer and retaining a mathematical model of the process, (2) the programming is inherently self-adaptive and has the capability of self-modification as required by varying plant conditions, (3) it has a powerful numerical computational ability, (4) memory is "built in" for the storage of limits, interim results, etc., (5) it provides direct control of the "set-points" of conventional control instrumentation and can also position power operators directly.

The majority of on-line process computer systems, both installed and being offered by manufacturers, are of the *general-purpose digital* variety. This means that they are internally programmed machines. In this type of computer the internal memory unit, usually magnetic core or drum, is used for two purposes—(1) storage of data concerned with numbers being processed or operated upon and (2) storage of all computer program instructions. It is this latter feature that provides these systems with their high degree

Continued on top of next page

BYRON WHITE

Consultant, Fischer & Porter Co.

CONTROL of pressure, temperature, level, flow, and a few other variables has, until recently, been enough to maintain most processes in acceptable working order. However, if instead of controlling to a fixed temperature we maximize the dollars gained across the process by changing the temperature it is sometimes possible to realize better efficiency and control. This is computer control.

Basically, computer control has to do with the calculation of some desired effect around a process (such as maximum dollar gain) and then so controlling the process as to accomplish the desired purpose. Computer control thus involves two functions—computing and controlling. As there are two philosophies and techniques for each function, there are four basic techniques available to the user.

In most computer control situations the computer combines known things such as flow rate, unit value, purity, mix ratios, etc., into a desired operating guide that is used in turn to operate the controller. The controller takes the calculated operating guide from the computer and turns it into set points for the flow, temperature and pressure controllers.

Calculating set points introduces the difficulty and the expense. We already compute once to obtain the operating-guide calculation. However, the equipment also must store and keep track of a mathematical model of the process and use this model as a guide to calculate new set points. This is the expensive (in both engineering and equipment) part of what we call "computer control"; it is part of the controller function, but it is only one way to achieve the effect we are seeking—to optimize the process.

There are two basic methods of making the computer—analog and digital. Further, there are two different approaches to the control problem itself—control can be based on calculation or experiment. Thus there are four techniques open to the user.

Computer: Analog or Digital?

The first major consideration concerns the choice between analog or digital systems. A digital system

Continued on next page

Mathewson—continued

of flexibility. Reprogramming for a completely different type of operation can be accomplished in minutes.

In addition to the common general-purpose digital computers, a number of other types of "computer" systems are becoming available. Most of these are special-purpose devices which might better be classified as sophisticated controllers of the instrument type. Some use the peak-searching principle, and some incorporate concepts such as game theory. Most are relatively small and inexpensive and accommodate only a few inputs. They are designed to handle specific control problems and are not useful as data reduction or information systems.

Other types of hybrid computers are starting to arrive on the scene in the medium-size category. These include digital differential analyzers which are designed more for control than for data reduction.

It is too early to evaluate the importance of the hybrid and special-purpose computer in tomorrow's era of computer control and data reduction. In the meantime, the *general-purpose digital computer*, specially designed for process application, is rapidly becoming established as a practical and powerful industrial tool.

White—continued

is more expensive, takes more equipment, and requires more know-how in application than an analog system, whereas analogs are familiar to instrument men (every proportional-band controller is essentially a little analog computer). However, digital techniques are more flexible, offer higher accuracy in performing some mathematical calculations, accept more variables, and lend themselves readily to automatic printout of data.

Set Point: Computation or Experimentation?

The second major consideration in the cost vs philosophy problem has to do with how the new set points are determined by the controller of the computer-controller. They can be established either (1) by computation or (2) by automatic experimentation.

Type 1—Control by computation and mathematical model.

A *mathematical model* of the process can be stored in the computer memory. Readings on the actual process then can be referred to the model and set points for the process obtained from the model. However, all coefficients and constants of the process equations must be known and remain constant. Very often not this much is known about the process, and this is where a large amount of engineering work is required before the application can be made.

Control from a mathematical model with only some of the coefficients and constants known is basically the same except that the computer must do a certain amount of curve fitting. That is, each time a reading is taken on the process, the coefficients and constants are readjusted to make the mathematical model more closely represent the presently known facts of the process. This requires a complex computer and a lot of engineering knowledge about the process. It is the most powerful—and most expensive—method of computer control.

Type 2—Control by automatic experimentation with the process.

An experimental change is made in a process input variable. After the process has stabilized, the controller (1) samples the quantity desired as given by the associated computer, (2) determines whether the last change brought good or bad results, and (3) makes another change accordingly. Control action seeks a maximum or a minimum of the desired quantity (zero slope), or it can seek any given slope of the process characteristic.

The process output can be an actual direct function of the process, such as percent product in a flow stream, or it may be a computed output, such as dollars gained across the process. The exact shape of the characteristic curve need not be known; little detailed information about the process is required. In the analog version, this form of computer control is so simple that it normally can be installed by the regular plant instrument man.

In the generalized case, control can be to some predetermined slope of the process characteristic curve—not necessarily the zero slope of a maximum or minimum. This type of control can be an efficiency or dollar-value control; it sometimes can be done without use of an associated computer. This is the least expensive type of computer control. The cost control comes in by choosing the coordinates of control such that the slope has a cost meaning.

The total costs involved in applying computer control involve six major factors:

1. Engineering, both in learning about the process and in application of the computer and control equipment to the process.
2. Conventional control equipment.
3. Computer.
4. Special equipment to adapt the input and output of the process to the computer.
5. Scanning and monitoring equipment.
6. Installation, including shut-down and start-up costs, and maintenance.

The most expensive form of computer control ($100,000 to $300,000), is the digital mathematical model with variable coefficients and constants. The least expensive ($5000-$15000) is the experimental analog model that can control on the slope of the process characteristic curve to any set-point (slope) value, including zero.

The fact that the interest in digital techniques is much greater than in analog techniques is a reflection of several factors—(1) digital techniques are more powerful mathematically and can accommodate more variables, (2) they have been refined to a high degree by the military and by business accounting applications, (3) few users appreciate that relatively inexpensive analog techniques are available for "computer control."

FEATURES OF DIGITAL COMPUTERS

Dr. ROBERT MCNAUGHTON
University of Pennsylvania

LARGE-SCALE DIGITAL COMPUTERS differ from small desk computers in that all the instructions and data for a computation are prepared in a program before any of the instructions are carried out. There are several important implications of this fact. Often decisions must be made in the midst of computation. For example, it may be necessary to carry out one series of operations if a>b and another set of operations if b>a. If a desk machine is used it is the human operator who compares a and b and decides what the machine is to do next. A large-scale digital computer must be capable of making its own decisions without human help.

A set of program steps which are repeated several times is called a loop. A loop cannot continue indefinitely, and so the machine must be capable of deciding when to stop. Thus machine loop control necesitates machine decision making. Data and instructions are kept in the storage, or memory, of the machine. This means that the machine must be able to modify its own storage without human help.

Thus, the main distinctive features are the ability of the machine to make decisions, its ability to control loops, its ability to modify its own storage, common storage of instructions and data, and its capacity to deal with instructions in the machine language.

Abstracted from ISA Paper PCT-4-58

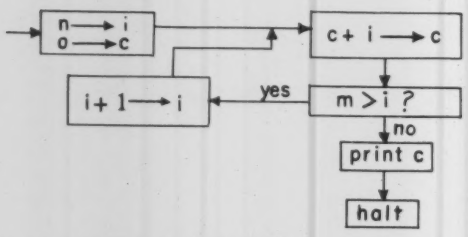

FIG. 1. FLOW CHART for $\sum_{i=n}^{m} i$; c represents the sum after each operation. Block "m> i?" establishes whether i has reached upper-limit m or not; if not, i is increased by unity in block "i + 1."

A Sample Routine

A simple exercise to illustrate the above rules and the fundamental points is a routine for obtaining the sum of all the consecutive integers from *n* to *m*, whatever *n* and *m* may be. What is desired here is to write a program with two unfilled storage positions, one for *n* and the other for *m*. We can get this sum, for a given *n* and *m*, by substituting these values in the two respective storage positions and then let the machine go through the routine. The routine can be used over and over agian.

To perform this computation the machine will add *n* and n+1, add n+2 to that, add n+3 to that, etc., until it has added in the last number *m*. These operations are an indefinite number of repetitions with slight variations. A loop is called for, and the program must provide for the machine deciding when to come out of the loop.

Let *i* vary from *n* to *m* consecutively over the integers; let *c* vary over the consecutive values of the sum. At the beginning of the computation i =n and c = 0; at the end of the computation i = m and:

$$c = \sum_{i=n}^{m} i.$$

The schematic flow chart is shown in Fig. 1. The arrow going into the box at the upper left of Fig. 1 indicates where the routine is to begin. Computation sequence is in the order indicated by the arrows. Each box shows the operation performed therein. The box containing "m>i?" is a decision-making box. The machine decides, on the basis of the answer to the question, which arrow to move along.

The loop is repeated if i< m, otherwise the machine prints out the value of c.

Another feature of large-scale computers is that they are general symbol manipulators and are not restricted to arithmetic operations. Thus machines are able to play chess, manipulate strings of symbols in algebraic and logical formulas, classify, and sort. This is another feature which distinguishes large-scale machines from small desk machines.

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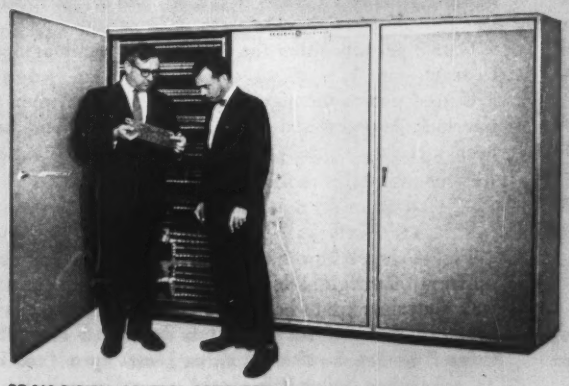

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FOR FIGURES IN A HURRY—FIGURE ON A GE COMPUTER

CIRCLE 42 ON READER-SERVICE CARD

M. H. ARONSON

Logical Design for Batch Process

THE value of a "logic variable" at any instant can only be 1 or 0—that is, it exists or doesn't exist.

There are two primary logic functions—*and* and *or*. These functions are best illustrated by considering switches connected in series or in parallel (Fig. 1). Switches in series must all be closed before the over-all circuit is closed. The pictorial representation of *and* shows that all inputs stop at the gate; hence the output is 0 except when every input has the value 1 (Fig. 1). The *or* function symbol shows that each input goes through the gate.

The first step in describing how a batch-type production process should operate is to describe what valves should open or close and in what sequence. The *sequence chart* provides a convenient means for extracting and recording this information (Fig. 2).

The sequence chart shows which valves will be commanded to permit flow at the controlled rate (black bar) or to close (absence of black bar) at each step in the sequence. Also, it shows what conditions must be met in order for the sequence to continue to the next step.

Control of Valve 1

Fig. 3 shows the signal functions which control valve No. 1; this pattern is repeated for all other valves.

Four gates are required for control of valve 1. Gate 1 produces the automatic signal; gate 2 produces the manual signal when manual control is desired; gate 3 permits either automatic or manual signal to reach gate 4; gate 4 permits the valve to operate *if the interlock is proper*—that is, if all conditions are proper.

Gate 1 (automatic signal) must receive two signals before it develops the automatic signal—one signal is from the selector unit; the other is the desired automatic control signal.

Gate 2 (manual) also must receive two signals—the selector must be switched to manual and toggle must be energized.

Gate 3 permits either the automatic or manual signal to reach gate 4.

Gate 4 passes the signal to the valve only when the interlock is energized—that is, all conditions have been met.

Interlock

Fig. 4 shows how interlock requirements are made up from the original description of the process and the way materials are to be combined.

Interlock signal for valve 1 is developed only when valve 2 is closed—that is, valve 1 can open (see Fig. 3) only when valve 2 is closed.

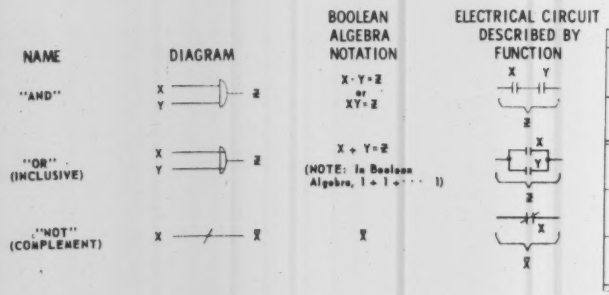

FIG. 1. BASIC LOGIC functions are "and", "or" and "not."

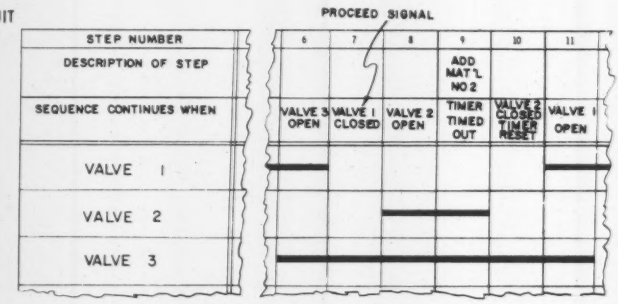

FIG. 2. PORTION of typical sequence chart. Process constraints include (1) valve 1 and valve 2 must not be opened simultaneously; (2) valve 3 must be open when valve 2 is opened. This is done by "interlock" signals.

with Alarm

The sequence chart and the basic logic functions AND, OR, and NOT permit the control of valves in any desired sequence, and with any desired relationships between valves. The term "gate" herein is a functional symbol, and does not refer to any hardware or equipment.

Interlock for valve 2 is produced (valve 2 can open) only when three conditions are met—valve 3 must be open, valve 1 must be closed, alarm is *not* energized.

Valve 3 can open when valve 2 is open *or* when alarm is *not* energized.

Alarm Circuit

Alarm circuits can be specified in the same manner.

In Fig. 5 the alarm signal (top) will appear when an over-limit signal appears.

The alarm signal will energize a flashing red light and horn because *and* gate 6 passes this signal (its other input is not present). The output of gate 6 prevents the steady red light from lighting because of gate 7.

When the acknowledge pushbutton is pushed, a signal appears at the output of gate 5. Gate 6 no longer operates, the flashing red light and horn are cut off, and the steady red light goes on.

To understand the reset function, it is first necessary to understand the "hold" function of an *or* gate (gate 1) whose output is fed back into itself via an *and* gate (gate 2). In this circuit an over-limit signal causes a signal to appear at the "hold" input of gate 2. As there is no signal at the other input, the conditions for an output signal are met, and a "hold" signal will appear at the input of gate 1. Now, even if the over-limit signal disappears, the alarm signal will remain.

The acknowledge signal from gate 5 is fed to gate 4 as another "hold" signal. Hence, if the alarm signal exists, gate 4 holds an acknowledge signal, even if the acknowledge pushbutton is released.

To reset the system, the reset pushbutton develops a signal into gate 3, which also has its acknowledge signal present. Hence a signal appears at the "not" input to gate 2, breaking the hold circuit—that is, no signal goes into gate 1 and there is no alarm signal (if the over-limit signal has been corrected).

Acknowledgement

This article is based in part on an article "Logical Development and Design of a Sequential Batching System," by J. P. Laird, E. I. DuPont de Nemours & Co., Wilmington, Del. The original work is ASME Paper 58-AUT-5, which also was published in IRE Proceedings, August, 1958, pages 44-54 (author offers reprints to any interested party). This paper was preceded by another paper by Mr. Laird—ASME Paper 57-A-151 on the same subject.

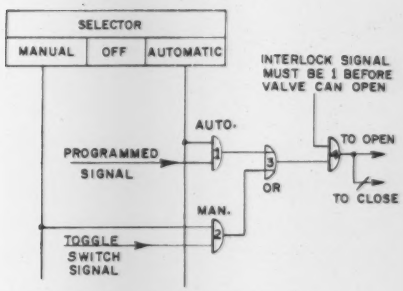

FIG. 3. CONTROL of valve 1.

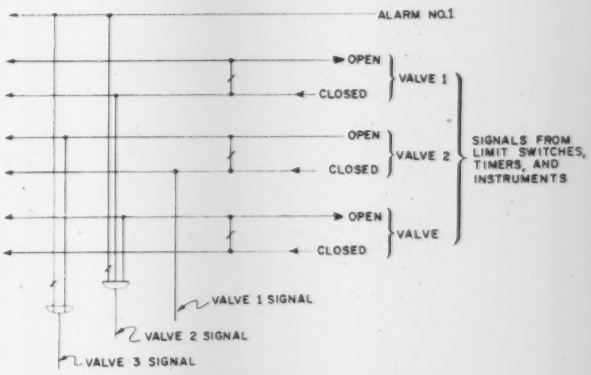

FIG. 4. INTERLOCK SIGNALS prevent hazardous combination and insure meeting all constraints.

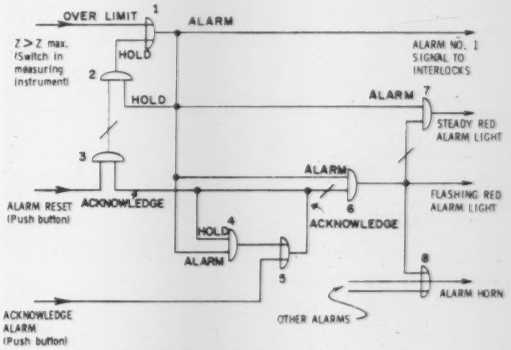

FIG. 5. LOGIC DIAGRAM of alarm requirements.

Dynamic Data

J. E. WESTWICK
Allison Div. of General Motors Corp.

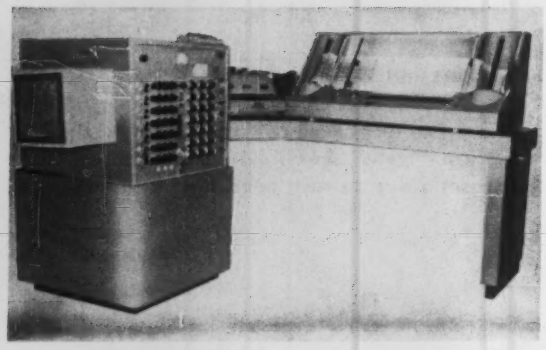

FIG. 1. OSCILLOGRAM analyzer and reader (Courtesy Benson-Lehner).

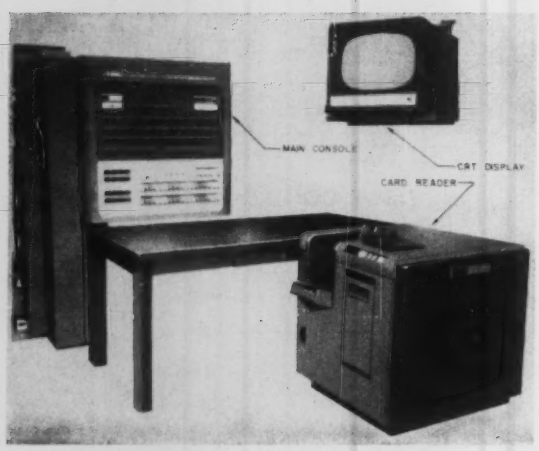

FIG. 2. IBM 704 COMPUTER main console, card reader, and CRT display unit.

Table 1—Techniques For Preparing Computer Input Data

Instrumentation Recording Device	Intermediate Analog Process	Intermediate Digital Process	Input to Computer
Tape Recorder	Oscillograph	Punch Cards	Card Reader
Tape Recorder	A/D Converter and Digital Recorder	Digital Tape	Tape Storage
Tape Recorder	A/D Converter and Digital Recorder		Tape Storage
Oscillograph	Hand tabulation	Punched Cards	Card Reader
Oscillograph		Punch cards from Oscillograph Reader	Card Reader
A/D Converter and Digital Recorder		Digital Tape	Tape Storage
A/D Converter and Digital Recorder			Tape Storage

ANALYSIS of high-frequency analog information can be a difficult and tedious process. The most popular types of final data presentation are oscillograph records, oscilloscope displays, voltmeter readings, and presentation forms from electronic filter systems. All have inherent shortcomings of poor accuracy, little versatility and time-consuming interpretation.

Consider, for example, acceleration measurements. The acceleration transducer develops an analog voltage signal, normally of a complex nature, proportional to the acceleration level. This signal is usually recorded on magnetic tape; an oscillograph recording then can be made from the magnetic-tape recording. This presentation is excellent for first-look determination of unusual events, but for more detailed interpretation the complex acceleration wave means little. The analog wave should be dissected for predominant frequencies, transient peaks, energy distribution, etc. Various electronic filter systems are used for this dissection, but with difficulty. A digital computer can be used directly for such difficult data analysis.

Basic considerations for the use of a computer for data analysis are (1) type of input to computer—manual, punched cards or magnetic tape, (2) programming the computer, and (3) selecting the type of final presentation desired—punched cards, magnetic tape, cathode-ray-tube display, or tabular printout.

Computer Inputs

The first consideration is selecting the information input method. There are three basic input methods for introducing analog data: (1) Point-by-point hand reduction of oscillograph data for punched-card input; (2) point-by-point semi-automatic machine reduction of oscillograph data for punched-card input; and (3) high-speed electronic analog-to-digital conversion of data for magnetic-tape or punched-card-input.

Hand reduction of oscillograph data is the least desirable method due to human error and time consumed. The procedure is simply one of tabulating amplitude points along an analog wave against the time base of the oscillograph. The tabulated figures are key punched onto data cards and fed into the computer. If this input method is the only one available to the instrumen-

Analysis by Digital Computer

Use of a digital computer for instrumentation data analysis requires consideration of (1) computer input and output techniques, (2) programming, (3) analog-to-digital conversion of information, and (4) types of instrumentation data analysis possible by the computer.

tation engineer, the value of the analysis obtained must be weighed against the necessary hand reduction of the analog data.

A faster method is *semi-automatic machine reduction* of oscillograph data. This is accomplished on an Oscillogram Analyzer and Reader (Fig. 1), which will punch data cards as the operator moves a curve-following pointer along the analog oscillograph trace. The operator picks a point to be considered on the analog wave and depresses a button that initiates the punching of a data card. The equipment accuracy is of the order of ±0.1% full-scale of the oscillograph paper. Speed of conversion from analog wave to digital point varies as a function of the proficiency of the operator; an average rate for an experienced operator is fourteen points per minute.* However, even this method of analog-to-digital conversion can be too slow when the amount of analog information to be analyzed is large.

The fastest and most accurate means of transforming analog data to digital data is by the use of *high-speed electronic analog-to-digital converter and magnetic-tape recorder*. The analog information is fed into the converter and the resulting digital information is recorded on magnetic tape.

The magnetic tape is either placed on tape units[1] as an integral part of the computer, or is played back onto the tape units of the computer to be made compatible for machine operation. Full-scale equipment accuracy of ±0.1% with digital sampling rates up to 100,000 points per second can be obtained from commercially built converters.[2]

Table 1 summarizes the various techniques for preparing the analog data for the computer.

Sampling Rate

Sampling rate is of prime importance in all input methods. The most-used theorem in Information Theory that applies to sampling rates is that of C. E. Shannon:[3] If a function of time f(t) is limited to the band from 0 to F cycles per second, it is completely described by giving its ordinates at a series of discrete points 1/(2F) seconds apart.

In other words, if the highest frequency in the data is F cps, the data is completely determined by giving its ordinates at a series of points 1/(2F) seconds apart. That is, the sampling rate required is 2F samples/second.[13] However, this is true only if (1) the sampled interval of the function f(t) is very much greater than the time interval of the sampling rate, and (2) the amplitude of each point is measured infinitely accurately. Thus the actual sampling rate used for instrumentation measurements is determined by considering:

1. The accuracy of the analog-to-digital conversion system—i.e., the error in measuring amplitude.
2. The total length of the information to be converted to digital form; the shorter the length, the more frequent the sample points must be.
3. The bandwidth of the information to be converted.
4. The accuracy required from the digital analysis.
5. The type of data analysis required.

The sampling rate is always a compromise; it must be determined by the instrumentation engineer for his particular project and field of investigation. The author's experience is that in most instrumentation measurements, a sampling rate of six to ten samples per cycle at the highest frequency to be analyzed is sufficient to describe the function to its original accuracy. This does not include the error of amplitude conversion.

For data analysis where digital reproduction of the original information is not necessary, a sampling rate of three to four samples per cycle at the highest frequency is sufficient. For example, such a sampling rate would be used for spectral density analysis.[5] There are numerous statistical types of data analysis where this sampling rate would be sufficient. It again depends on the type of analysis to be performed by the computer.

Types of Output

The computer can present results in tabular form on a high-speed printer[4], on punched cards on a card punch unit, on magnetic tape[1], and in graphic form on a cathode-ray-tube (Fig. 2). The output mode is spe-

*Based on the Benson-Lehner Oscillogram Analyzer and Reader, Oscar, Model E.

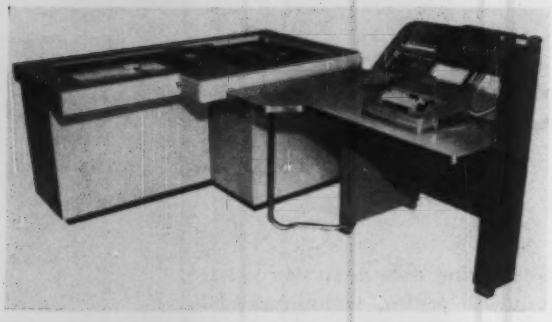

FIG. 3. X-Y PLOTTER. (Courtesy Benson-Lehner).

Table 2—Techniques for Obtaining Data From Process Computer

Output Medium of Computer	Intermediate Process	Final Form
On-Line Printer		Tabular Printout
CRT Plotter		Photograph of CRT
Magnetic Tape	Card Punch	Graph from X-Y Plotter
Magnetic Tape	Off-Line Printer	Tabular Printout
Card Punch		Graph from X-Y Plotter

cified by the analysis program introduced into the computer. Results should be recorded on magnetic tape when lengthy tabular presentation is anticipated; the magnetic tape can be removed from the computer and the tabular printout handled by separate equipment which reads the results from the tape.

When *graphic results* are desired, two methods are possible—cathode-ray-tube presentation or x-y plotter presentation. The CRT presentation (Fig. 2) is an integral part of the computer operation and the visual display resulting can be photographed for a permanent record. For larger expanded graphs, the punched cards obtained from the computer are fed into an off-line x-y plotter (Fig. 3). This method is slower than the CRT method but expanded graphs of multiple curves can be obtained.

Table 2 summarizes the various techniques for obtaining the data from the computer.

Computer Programming

Computer programming is the method of instructing the computer as to what to do with the input data and how to present the results obtained.

A program consists of a list of machine commands written by the programmer. The information input is governed by commands so that complete control is maintained as to how much data will come in at one time. The mathematical operations to be performed by the computer also are specifically written out in machine commands; the final presentation of results is controlled in the same manner. The written commands are normally punched on data cards and fed into the computer before any raw information is introduced.

Most large digital computers have interval checks and computing stops that help catch the errors of the programmer. Even with these checks, the programmer may make an error that will present erroneous results. For this reason a program should be tested on known information, and checked to make sure the computer results are the same as the known calculated results.

The practical accuracy of a large digital computer is only as good as the mathematical operation performed and the program introduced; the computer does not introduce errors of any significance in instrumentation data analysis operations. For example, the IBM 704 digital computer (Fig. 2) operates on numbers as small as 10^{-38} and as large as 10^{+38} with no error.

Computer programming can be difficult or relatively easy, depending on the computer available and the type of programming necessary; let us consider the programming of the IBM 704 digital computer. The unit has two main methods of programming—*Symbolic Coding* and *Formula Translation* (Fortran) coding. Symbolic coding is the basic method used for logical use of the computer and requires detailed knowledge of the many machine commands. This method is normally used by a programmer who can take a mathematical formula and express it as a list of symbolic commands. It takes a great deal of time but allows complete control of computer operations.

Fortran coding was recently developed by IBM for use by the average engineer. The coding can be taught easily because it consists simply of writing the mathematical expression the computer is to follow in its operation. The computer recognizes the equation and translates the equation into the machine actions necessary to perform the required operation. Fortran coding sacrifices computer control for simplicity of programming, but it is a big step in allowing the translation of mathematics into machine language within the computer, rather than by the programmer.

Types of Computer Analysis

The types of instrumentation data analyses possible with the digital computer are numerous and include:

1. RMS (root-mean-square) calculations versus time of occurrence.
2. Power Spectral Density (power versus frequency).
3. Peak Wave versus Time (determination of peaks for a given analog function versus the time of occurrence).
4. Velocity and Displacement Analysis (determination of analog velocity and displacement from a given analog acceleration).
5. Three-Dimensional Analysis (analysis of three parameters to determine vector resultants, frequency, and angle).

These are not the only functions that the computer can perform, just typical examples.

Spectral Density Analysis

Spectral density analysis indicates the amount of power (amplitude squared) that is present within a given bandwidth of frequencies.[5] This type of instrumentation data analysis is particularly meaningful for complex wave information and is common in vibration and other complex measurements.

Electronic analog systems have been developed for this analysis using wave analyzers and mean-square-law detectors. The accuracy of such systems is in the order of $\pm 10\%$. However, computer programs have been written for spectral density information[7] which result in accuracies of $\pm 1\%$.

Accuracy is an advantage of the digital computer for this analysis, but more important, the program allows a detailed examination of the information. For example, *trend removal* (the removal of low frequencies from the analysis) can be accomplished by the program. If trend is not removed, it is possible there will be an indication of large power concentrations around zero frequency. As there can be no power at the origin, such an indication is erroneous. Statistical examination of power peaks and valleys also can be accomplished.[5]

Root-Mean-Square (RMS) Analysis

RMS data presentation is a convenient way of showing the voltage levels of a complex wave over a period of time. RMS measurements cannot be expressed for one instant in time but, rather, are averages over a known time interval. There are a number of electronic voltage-measuring devices that indicate RMS for a fixed averaging interval (0.25 sec to 10 sec), depending on the instrument. The accuracies of these instruments vary from $\pm 0.1\%$ to $\pm 4\%$ full scale.

RMS analysis of complex analog waves can be handled easily by a digital computer. The accuracy of the results depends not on the analyzing medium but on the accuracy of the original information and the method of input to the computer. The biggest advantage of the computer over the electronic devices is that the averaging interval for each RMS voltage result can be varied as the programmer desires. The mathematical operation for each RMS result in an interval between t_1 and t_2 is:

$$\text{RMS} = \sqrt{(X_1^2 + X_2^2 + {}_3^2 \ldots X_n^2)/n}$$

where X_n = amplitude of voltage at each point, n = sample points between t_1 and t_2.

Motion Analysis

Given an analog complex wave representing an acceleration, it often is desired to know the velocity and displacement. The integration of acceleration is velocity, and the integration of velocity is displacement. The computer can be programmed to do integration by the summation of areas under the acceleration curve and thus obtain the desired velocity and displacement complex waves.

The first integration would be handled as follows:

$v_1 = X_1 \Delta t$

$v_2 = (X_1 + X_2) \Delta t$

$v_3 = (X_1 + X_2 + X_3) \Delta t$

$v_i = (X_1 + X_2 + \ldots X_n) \Delta t$

where v_i = velocity of point i, i = 1, 2, 3 . . . n; X_n = amplitude of acceleration at each n^{th} point, t = time between samples; n = samples taken over integration period.

This summation process can be programmed so that a graph of velocity is formed by considering each velocity point, v_1 to v_i, and plotting them on the CRT. Corrections must be made in the program for the "original velocity" before integration to dynamic velocity can be done.

Double integration to obtain the displacement wave then follows by taking each term of the velocity series and forming a displacement summation series. There are more refined methods of obtaining the above integration by Numerical Analysis Theory[8]; the procedure of integration by summation described is an indication of only one procedure.

Peak Wave Analysis

The need often arises to determine the peak values of a complex wave with respect to time. This type of analysis can be done painstakingly with an oscillograph record, but it is much easier to determine by using the computer as a data-reduction medium. The computer can tabulate the peaks and the time of occurrence in easily readable form.

Three-dimensional Analyses

Dynamic information with more than one degree of freedom is nearly impossible to analyze using conventional electronic devices. For example, consider a three-degree-of-freedom fixture on which acceleration is measured in the three dimensions. Each degree can be analyzed separately by normal means, but combining the results to find the resultant vector acceleration and frequencies is difficult. The digital computer is the answer. The information is introduced for all three degrees of freedom, and the proper program gives the necessary vector analysis. This concept is equally valid for force and stress.

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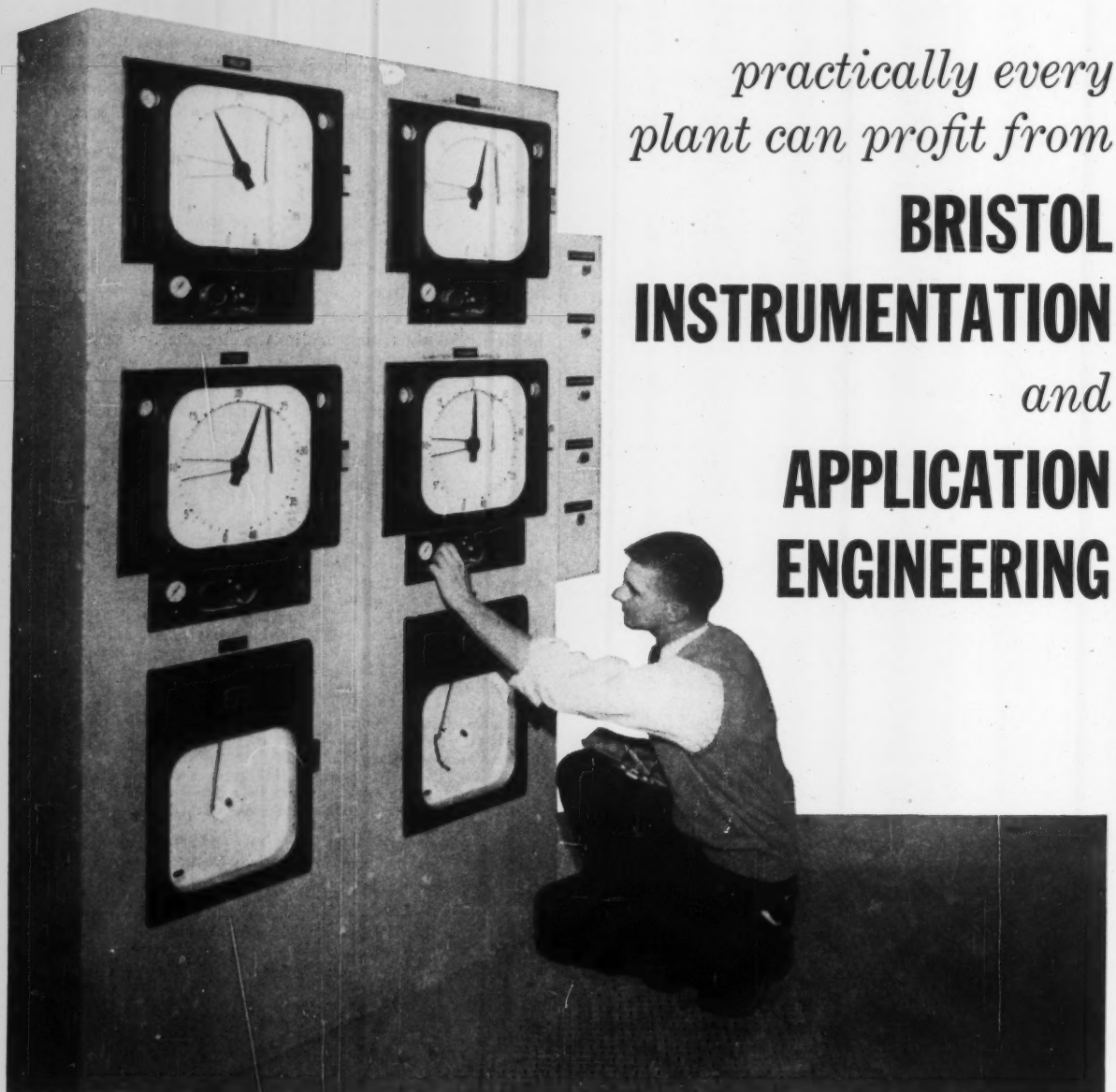

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Data Loggers

CONCLUDING THE SURVEY
BEGUN IN THE NOVEMBER ISSUE

MILTON H. ARONSON

Hanson-Gorrill-Brian

Hanson-Gorrill-Brian, Inc. offers Data-Masters which are assembled from standardized modules as required for the application. The modules are basic items of instrumentation, stepping switch assemblies and relay banks. Modules are all connected into the system at gold-plated taper-pin boards. New modules may be added at any time to increase scope or change function.

Inputs include any variable that can be measured on an indicating or recording instrument, such as temperature, pressure, resistance, millivolts, etc. Read-out is on IBM output writer, tape punch, or any type printer. Controls are provided for "continuous", "on-demand", or "timed" log, as well as to stop the logging cycle on any point for visual monitoring and calibration.

Type 1 (Fig. 30) is available with 25 or 50 input points. Inputs may be from any type transducers, but voltage spans of all inputs must be the same. Type 1 uses a gold-plated stepping switch input programmer and a Bristol Model 565 circular-scale Dynamaster Indicator driving an electro-mechanical encoder.

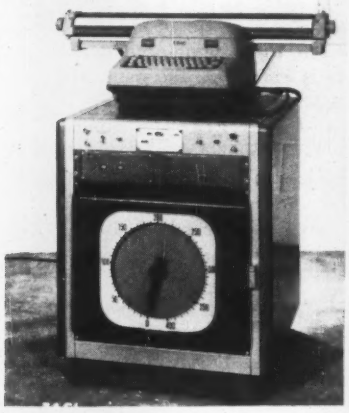


Fig. 30. Hanson Data-Master Type 1.

Type 2, available with 24 or 48 input points, uses a Model 560 Bristol Multi-Point Dynamaster recorder and offers strip-chart recording of variables along with the typewritten log. Programming of the inputs is performed by the recorder.

Type 3 (Fig. 31), available in multiples of 25 or 50 inputs, is similar to Type 1, but can accept any number of different types of inputs. Many more optional features are available in Type 3 including continuous scanning with alarms, zero suppression, digital multipliers, etc. Input programming by mercury wetted relays instead of stepping switches is also an optional extra.

Fig. 31. Data-Master Type 3.

Type 4 (Fig. 32) is a suitcase-sized version of Type 1.

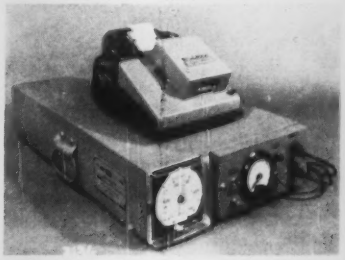


Fig. 32. Data-Master Type 4.

The Data-Master Type 5 (Fig. 33) scans a number of pressures, measures them, and records the data in digital form. It is particularly suitable when minimum switched volume is required for accuracy and

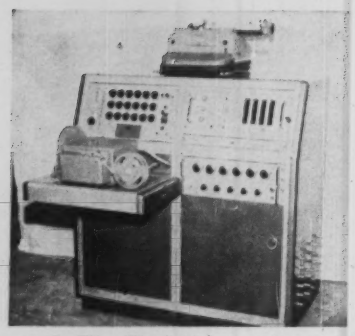


Fig. 33. Data-Master type 5.

speed. The Type 5 comprises an input programmer to position the scanner, one to four 12-position rotary pressure scanners, a variable reluctance pressure transducer, a 10-kc FM oscillator that provides a linear frequency deviation from 10 kc to 12 kc for the full-scale input of the pressure transducer, a counter that counts the number of cycles of the FM oscillator for a given gate time, a thyratron storage resistor which is fired by the count from the counter and closes relays in the translator, and an output programmer that controls the operation of the typewriter and tape punch.

Hanson-Gorrill-Brian, Inc. also manufactures custom loggers under the name Data-Liner.

Applications to date have been in various process industries. About 20 loggers have been installed to date, for a total of about 2,000 channels.

Honeywell

Analog Data Recorder Transcriber (ADRT) 3000 is a standard Honeywell Data Handling System which provides data logging, alarm scanning, digital indication, and computing functions (Fig. 34).

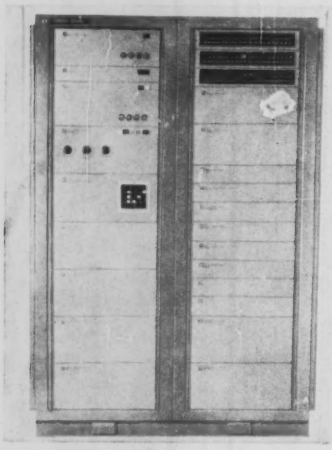


Fig. 34. Honeywell ADRT Series 3120 has 120 channels.

The data logger receives signals from primary sensing devices in the plant. The system automatically scale factors the input signals—readings are directly in degrees, pounds, cubic feet per hour, revolutions per minute, and so on. Thermocouples are automatically linearized within 1°F over their entire usable range. A pinboard programmed computer automatically solves arithmatical equations involving both analog inputs and fixed constants.

Data is normally typed out on log sheets but may be read out on punched paper tape or punched cards.

Decimal pinboards permit easy setting of span, zero and alarm set points to the actual digital value.

During scanning, the system monitors all points at high speed and immediately warns the operating personnel of off-normal conditions. The alarm annunciator panel provides an individual light for each off-normal variable. A printed record shows all variables that have exceeded their normal operating conditions.

The ADRT 3000 is calibrated to an accuracy of 0.1% of reading or 1 digit, whichever is greater.

Logging speed is 2 points/second; alarm scanning speed is 7 points/second. Readout is 4 digits: 0 to 9999, plus or minus.

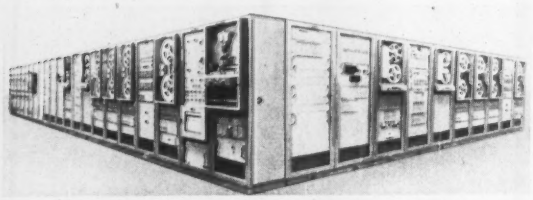


Fig. 35. Honeywell test logging system.

Modular analog-digital data acquisition systems for test purposes are also offered by the Industrial Systems Division of Minneapolis-Honeywell. Fig. 35 shows one such system. The transducer equipment includes bridge balance and calibrate facilities, thermocouple reference junction ovens, and low-level differential amplifiers (Accudata II amplifiers). The amplifier can handle both transient and steady state data because of high frequency response.

The analog instrumentation consists of the Honeywell 3170 magnetic tape system, permitting up to 10-kc response with a degree of accuracy surpassed only by the digital instrumentation. The Honeywell "Visicorder" oscillograph also is used to permit rapid viewing of test data, either on line or after playback of the taped signals.

The digital instrumentation operates at speeds up to 10,000 sampled conversions per second and provides accuracies of 0.1% from input of amplifier to final recorded tape. It is entirely solid state. The information is commutated by a multipole electronic switch into a high-speed converter. The number of commutator poles can be expanded almost indefinitely; a typical system utilizes a 60-pole unit. Additional channels can be accommodated on a plug-in basis.

Honeywell loggers have been installed since 1955, primarily in refineries, chemical plants, power plants and research and test installations. Today 40 of these installations are logging an average of more than 170 channels each.

Kearfott

Scanalog 200 (Fig. 36) is designed to provide monitoring, logging and alarm for up to 200 temperature, pressure, liquid-level or flow transmitters. The basic system features (1) expansion in capacity to 1024 points, (2) scanning rates of 4 points per second by electromechanical switch or solid-state switch at rates of 100 points per second, (3) variable scanning rates (operator's option), (4) computational capabilities for closed-loop control, (5) solid-state circuitry.

Consoles contain patchboards, programming equip-

ments, reference voltage junctions (for temperature transmitters), range selectors, punched-tape conversion equipment, memory circuits, solid-state analog-digital converters, and regulated power supplies.

IBM electric typewriters with 30″ carriages are capable of in-line printing of 100 5-digit words. The control/display panel contains manual control for selecting scanning rates, automatic or manual logging, and data identifying operator, time, day, run number and type of run. A 24-hour clock with reset also is provided. A bank of 200 numbered lights correspond to the specific points being monitored and provide a visual "off normal" display.

Also offered is a data-logging digital computer that provides a total capacity of 40 data channels.

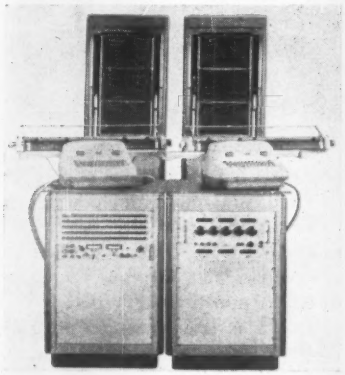


Fig. 36. Kearfott Scanalog 200.

Additional capacity can be provided as necessary. Basically the computer incorporates encoders for either potentiometric signals or will translate synchro shaft position into digital form. All necessary storage, data handling components, printers and alarm circuits are incorporated in the computer console.

Data logging at any discrete time interval is accomplished by the decimal printer which indicates the channel being logged by number and prints following data in black, red, or with asterisk(*) to show tolerances.

Punched card or tape also can be provided. An alarm circuit, triggered by a value exceeding tolerance, will turn on a light corresponding to the particular channel on a supplementary display.

Applications of Scanalog are in the nuclear and process industries; 1 installation has 200 channels.

Kin Tel

The simplest Kin Tel digital system for multi-channel data logging typically consists of a 453M scanner, a Kin Tel 501 digital voltmeter, and one of several commercially-available ten-line parallel-entry printers (Fig. 37). This system is capable of scanning 400 one-wire, 200 two-wire, or 100 four-wire inputs. Scanning rate depends on the stability and the actual difference in input voltage amplitude between channels. An average figure might be one channel every two or three seconds. The system provides automatic ranging and polarity indication and measures voltages from ±100 microvolts to ±1000 volts with 0.01% or ±1 digit of reading accuracy. It provides both visual and printed indication of the input voltage and the channel being

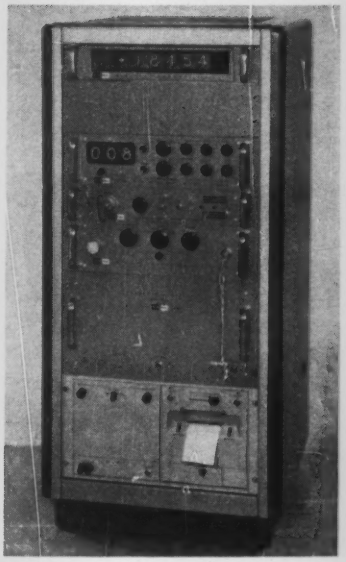


Fig. 37. Kin Tel System.

scanned. Delivery, currently, is off the shelf.

Adding an a-c converter to the basic d-c digital voltmeter will expand this basic system. This would permit a-c measurement in the range from one millivolt to 1000 volts, 30 cps to 10 kc. A preamplifier increases d-c sensitivity to 10 microvolts. A Model 454-ER-486 converter can be added to drive an IBM 526 card punch. Another converter can drive a paper tape perforator, and a Model 465 Go/No-Go voltage comparator provides Go/No-Go indication of a-c or d-c voltage levels.

Leeds & Northrup

L&N offers logging systems of various sizes with alarm, log-scan and trend-recording features. Fig. 38 shows a small portable system. Fig. 39 shows part of a 600-channel system with trend-alarm typewriter and log typewriter.

Scanning is done by electromechanical switch at rates up to 5 points per second. Logging is performed at 1 point per second.

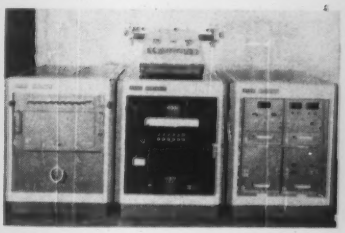


Fig. 38. L&N portable system.

Analog-to-digital conversion is done by shaft encoder on the shaft of a self-balancing potentiometer.

Scanning for off-normal conditions is performed either during or between logging cycles. An alarm memory also is available which permits printout when a channel first departs from normal, and again when it returns to normal.

Several variations in display are available, including visual display on an annunciator panel. Alarm setters can be furnished for individual channels or groups of points.

Fig. 39. L&N large system.

Logging can be periodic or on demand, and it can be interrupted for readout of trend or alarm.

More than 21 data-logging installations have been reported in the published literature, in missile-test, process, and other applications; eleven of these total about 1040 channels. Largest reported system is 600-channel unit at Public Service Electric & Gas Co., Bergen, N. J.

Librascope

Librascope offers special-purpose logging systems, in addition to their familiar computing systems. The systems use the Librascope commutator-disc shaft converter, flow computers, digital totalizers, etc.

Offered is a digital flow data system in which orifice signals are sent to flow computers which feed a totalizer. A scanner selects the output of any given totalizer and causes a card to be punched or a typewriter to log the data. The date and time also can be included. No loss of count is occurred during readout because a mechanical counter stores the pulses during the readout period.

Fig. 40 shows a data logger built for evaluating a fire-control system, which prints a record of 20 analog

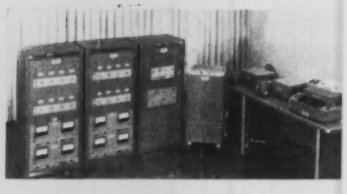


Fig. 40. Librascope Model 208.

variables. Twelve variables are scanned and recorded at 3-second intervals; the 8 others are recorded as needed. The data is essentially simultaneous because all 20 variables can be recorded in 800 microseconds.

These specifications are met by positioning 20 binary-coded decimal shaft converters (not shown) in relation to the analog variables, programming a scan matrix to sample the data at the specified times and store it temporarily on a magnetic drum, and employing recirculating and readout circuits to operate a high-speed paper tape punch. After the trial run, the information on punched tape is fed through a seven-hole tape reader, converted to six-hole Flexowriter code by a relay matrix, and prepared in printed form by an electric typewriter.

Approximately 8 logging systems of various types have been installed to date, particularly in evaluation of weapons systems.

Monroe Calculating Machine

The new Monroe DATA/LOG series MC-203 (Fig. 41) offers possibilities for data logging because it

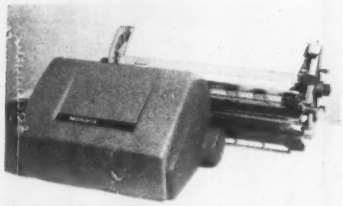


Fig. 41. Monroe MC-203.

features parallel entry, three to 14 decades per cycle, 2½ cycles (prints) per second. Options include red or black printout on command, externally controlled carriage return from any position, vertical spacing on command, special characters and symbols, separate keyboard for manual entry, punch tape output.

The even newer MC-215 is a serial-input logging unit with either fixed or programmable tabulating carriage. Digit entry is 20 per second; 142 print cycles per minute; up to 11 digits per print.

Well over 300 logging systems of various types have been installed to date, particularly in process and manufacturing control. These comprise a total of several thousands of channels of logged data.

Non-Linear Systems

Non-Linear makes a complete line of items which, connected together, can perform a wide variety of data logging jobs. The basic building blocks include digital measuring instruments (voltage, ratio, or resistance), AC to DC converters, low level pre-amplifiers, input scanners and serial converters and coding matricies.

The input scanners have capacities from 100 to 1000 input channels. The switching device used in NLS input scanners are specially designed, oil-immersed stepping switches with gold-plated contacts and diallyl phthalate insulation. Controls permit starting and stopping at any input channel and stopping or automatically recycling when the end of each scan is reached. An over-ride timer prevents the entire system from "hanging up" on one input channel in the event of a temporary failure. A digital readout on the input scanner indicates the number of the input channel being measured.

The serial converters and coding matrices permit operating tape punches, card punches, electric typewriters and Flexowriters which require digital input in time serial form from the parallel decimal output of the digital measuring instruments. The digital measuring instruments may be directly connected to paral-

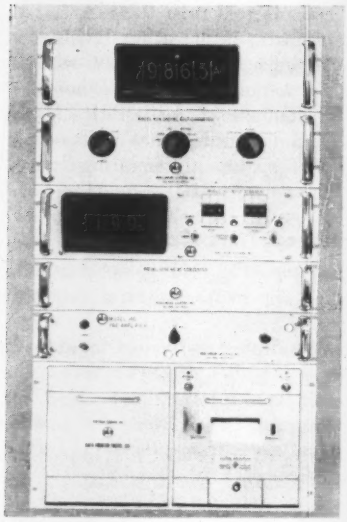


Fig. 42. Non-Linear system.

lel input type recorders such as Clary printers, Hewlett-Packard printers and some card punches.

Fig. 42 shows a typical data logging system consisting of an NLS 161 Input Scanner, and NLS Model M24 digital volt-ohm-ratiometer, Model 125C AC to DC converter, a Model 140 DC Pre-amplifier and a Model 155 Data Printer. The system measures up to 200 channels of input data. The input data may be AC voltage or DC voltage from 10 microvolts to 1000 volts. DC voltage ratio (using any value of reference voltage from ±1 volt to ±100 volts without readjusting the Model M24), and resistance from 0.1 ohm to 10 megohms. Measurements of DC voltage, DC voltage, DC voltage ratio and resistance are scanned, measured and recorded at the rate of 2 channels per second.

Approximately 22 logging systems of various types have been installed to date, particularly in the electronics weapons systems and semiconductor manufacturing industries. These comprise a total of about 13,200 channels of logged data.

Panellit
Information Systems, Inc.

Information Systems (formerly Panescan Div. of Panellit) offers the 607 logging-scanning system, the 627 logging system, and the 609 logging-computing system.

The 607 dual-function information system (Fig. 43) records process variables such as temperatures, pressures, flows, levels, etc., once an hour automatically. During the period between logs, the system continuously scans those same process variables to see that they are within limits pre-set by the operator. Variables found outside the limits are printed in red in an off-normal area at the bottom of the chart and also in red during hourly or demand logging to indicate their "off-normal" character. The system also will log all process variables at any time the operator demands. The printed data also can be punched on cards or tape for computer input.

Input selection is accomplished by telephone-type stepping switches which step at a max rate of 5 points per second. Signal switches have gold-plated contacts.

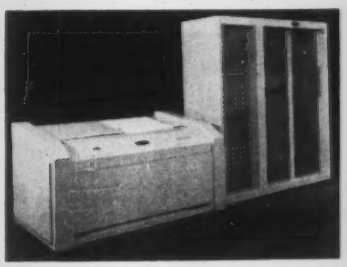


Fig. 43. ISI 607 system.

Alarm comparison is achieved by measuring the difference between the alarm limit settings and the input signal. High and low alarm comparisons are made simultaneously. The alarm settings are made on ten-turn potentiometers with duo-dials. Forty-eight potentiometers are furnished for each 75 input points and patch boards program the potentiometers. Connectors are furnished for external potentiometers with a capacity of up to two per input point.

Analog-to-digital conversion is accomplished by a null-balance method. Linearization of non-linear input signals is accomplished by converter.

A digital clock prints out time of day and initiates periodic logs. A loss of power feeding the clock or any associated integrating devices is indicated on all logs until the devices are reset.

System accuracy is not less than ± one digit plus ½% full scale.

A standard-cell calibration reading is made within a second of the last log point. A check made on the comparator used for off-normal indication is indicated on the last point on the log sheet.

ISI also has a 627 logging system with the same specs, but without the scanning feature.

Also available is a 609 information and computer system which uses a general-purpose digital computer for five independently programmed operating modes —(1) on-line monitoring of process variables and alarms, (2) on-line continuous data processing and logging, (3) on-line performance computation, (4) on-line automatic process control, and (5) off-line general purpose computation. All operating modes function independently; they do not disturb or delay each other. Programming is by punched paper tape.

Mercury-wetted relays are used for scanning; binary progression conversion is used. Machine speed is so great that the continuous on-line functions use up only a negligible part of the computer time at scanning speeds of 5 points per second.

Since 1952, ISI and Panascan have installed about 70 of the 607 and 627 systems in refineries, chemical and atomic plants, etc. These comprise about 38,000 channels in operation in the field. About five 609 systems are in production for 1960; these will have about 1400 channels.

Packard Bell

Packard Bell's analog-to-digital conversion and data processing system (Fig. 44), developed for the Applied Science Corporation of Princeton, N. J., digitizes the pulse-amplitude-modulated output of an ASCOP M-Series ground station. It records the data along with real time on magnetic tape in format suitable for off-line operation with a Bendix G-15 Computer, and pro-

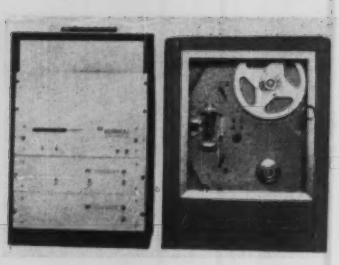


Fig. 44. Packard Bell System.

vides for on-line operation with the Computer. It digitizes up to 9 channels per frame and generates computer control signals. The equipment includes a Multiverter M-2, two MC-72 digital-module mounting cases, two PDM record and playback channels, and a Bendix MTA-2 tape transport.

Potter Instrument

Potter offers data-processing systems based on its extensive line of tape handlers, high-speed printers, tape readers and counting and data storage elements.

Fig. 45. Potter high-speed system.

Fig. 44 shows a typical high-speed data handling system which includes the RAM (Random Access Memory), 902 Magnetic Tape Handler, power supply and memory storage cabinets and "Flying Typewriter" printer. With the system, ½ billion bits of data can be stored in the RAM, converted to magnetic tape as a read out signal and printed out at speeds of up to 86,000 characters per minute.

Radiation, Inc.

Radiation specializes in telemetered-data-reduction systems.

The data-reduction system of Fig. 46 is a part of the test facilities of AFMTC-Cape Canaveral, and was designed for use with Project Vanguard. The system collects, digitizes and records real time PPM/AM, FM/FM and PWM/FM telemetry information during Vanguard satellite test firings. Simultaneously with 16 channels of PPM information, 12 analog channels of FM/FM data or 45 channels of ASCOP PWM/FM data may be digitized and recorded, making two independent systems, both capable of operating in real time.

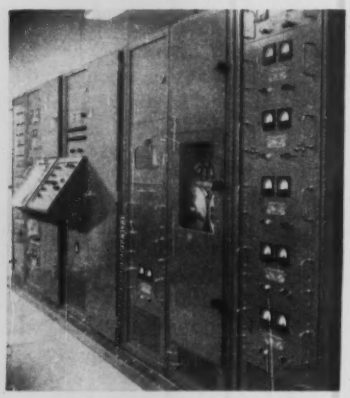


Fig. 46. Radiation system.

Stromberg Time Corp.

Stromberg's Transacter (Fig. 47) is automatic all-purpose data-gathering system for a central data-processing office.

Transacters accept multiple prepunched input media of varying thickness containing repetitive transaction information. They emit fixed information such as location codes and programming instructions. The composite message is automatically transmitted to a Compiler in the central office.

Fig. 47. Stromberg Transacter.

The output Tape on which a Compiler records information is suitable for immediate use and can be fed directly in communications systems, automatic typewriters, punched-tape to punched-card converters for tabulating equipment, or electronic data-processing equipment. Self checking facilities throughout the system verify the accuracy of the output message.

Telecomputing Corporation

The Data Instruments Division of Telecomputing offers general-purpose (DILOG 611) plus special-purpose logging systems based on its line of voltage and shaft digitizers, digital readouts (Teleducers), and programming devices (circuit scanner). Fig. 48 shows a typical system comprising a Telecordex 8A digital readout console with programming features, electric typewriter, and punch card unit. A scanning type programming unit is available to adapt the system to multi-channel analog-type input signals.

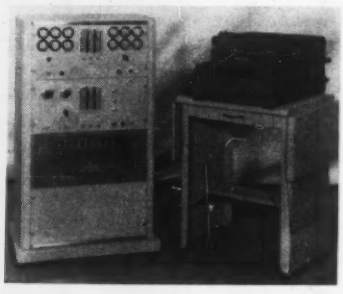


Fig. 48. Telecomputing system.

The program unit uses rotary selector switches to scan the inputs and also provides supplementary channel identification. Scan rate is 0.9 second per step.

The digital conversion can be performed by Teleducer Type 42 or Telecordex Type 8, both based on use of the Telecomputing shaft digitizer.

A new Decommutator Type 90 is available for use with PAM and PDM systems.

Most applications have been in wind-tunnel, chemical, process, and atomic-energy applications. About 55 installations comprise a total of about 11,000 channels of logged data.

Thermo Electric

Thermo Electric Co., Inc., offers systems for periodic or continuous monitoring of variables, or for printout of variables exceeding set points (Fig. 49). Standard multi-point recording, printout, or typewriter systems can be used with the Thermo Electric Monitor. Conversion is by self-balancing potentiometer indicator

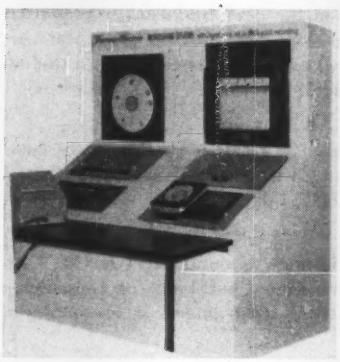


Fig. 49. Thermo Electric Monitor.

with an encoder on the slidewire drive shaft. A translator actuates a printer to show code or point numbers, temperatures, speed, etc. Date, time, code or point number, temperature, etc. also may be typed.

Approximately 40 monitoring systems of various types have been installed to date, particularly in the power, chemical and petrochemical, atomic, aircraft industries. These comprise a total of about 4000 channels of monitored points.

Vapor Recovery Systems

Vapor Recovery offers VAREC special-purpose data gathering and reduction systems (Fig. 50) for measuring and logging variables associated with the storage and transportation of liquids.

The system is based on use of transmitters which convert liquid level, temperature, pressure and flow (positive-displacement meter) into pulse-code digital signals. A receiver translates these signals into visual or printed form.

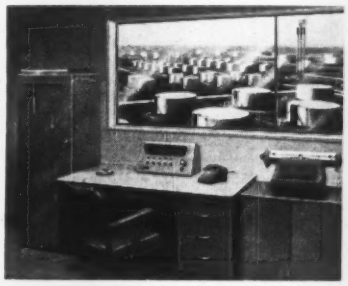


Fig. 50. Varec system.

Logging rate is approximately 10 points per minute.

Operation modes include (1) manual operation without logging to obtain a visual indication of any variable in the system, (2) manual control of scanning-logging cycle, (3) automatic control of scanning-logging cycle.

Approximately 20 logging systems of various types have been installed to date, particularly in the petroleum and petrochemical industries. These comprise a total of hundreds of tanks, valve control positions and alarms.

General Electric

The GE 309 (Fig. 51) automatically counts and records the occurrence of selected events in a process. The primary application is in logging of gage measurements on a rolling mill. The recorded data would include *total feet of strip* and *total feet of on-and off-gage* strip produced by the rolling mill. The logging system is normally operated by the process. In the basic system, signals from the sensors are sent to the counters until the end of the process run, or until the operator desires counting to stop. The totals are then automatically printed out on an electric typewriter.

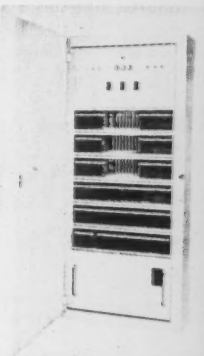


Fig. 51. General Electric 309 Logger.

B & F Instruments

B&F Instruments, Inc., offers multichannel recording and plotting systems (Fig. 52) with channels numbering 24, 48, 72, 96, etc. System can accommodate any type of transducer. All channels are separate—one can be a strain gage, one a resistance thermometer, load cell, EMF-type, etc. Basic scanning rate is 1 and 2 seconds per channel; faster scan is possible. Datex shaft encoder and digitizing equipment can feed summary punch or logger.

About twelve systems are in operation, mostly with resistive pickups, totalling about 1200 channels of logged data.

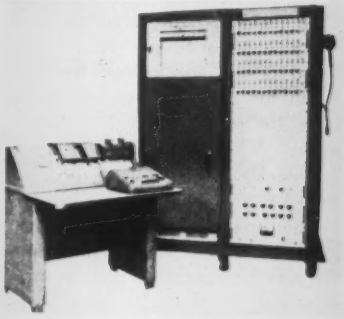


Fig. 52. B&F logger.

ELECTRONIC

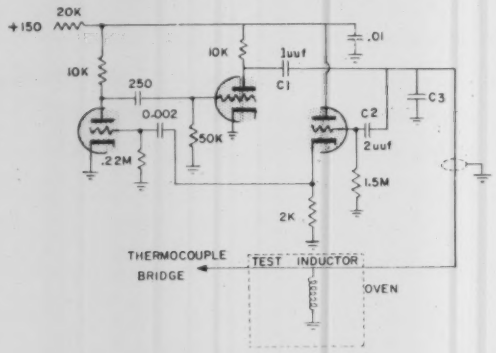
The circuit is the heart of all electronics. Here are 3 more basic and interesting circuits. Unless marked, resistors are in ohms, capacitors in microfarads.

OSCILLATOR TESTS TEMP COEFFICIENT OF COILS

The temperature coefficient of inductance of a coil is a function of nine things: (1) frequency, (2) and (3) resistivity of and temperature coefficient of resistivity of the conductor, (4) and (5) temperature coefficient of linear expansion of both the conductor and forms, (6) conductor shape, (7) form shape, (8) winding pitch, and (9) number of turns. To minimize the temperature coefficient of inductance, the number of turns must be kept small; wide conductors which are widely spaced and which have a low temperature coefficient of resistivity should be used. Unfortunately, all this tends toward a large coil with a low Q.

The circuit shown was used to test inductors and establish their temperature coefficient of inductance.

The inductor was tested as part of a tuned circuit of a highly stable oscillator. The change in frequency of the oscillator was measured as the temperature of the coil was varied. A precise method of measuring this frequency change consisted of beating the test oscillator with a signal from the primary frequency standards of the General Electric Company. These frequency standards had been in operation for many years and



their accuracy was known to exceed that required by this work. The difference frequency was measured by means of an audio oscillator and oscilloscope.

A Franklin oscillator was satisfactory for this application. It was found that the stability of the Franklin oscillator could be increased by the addition of a cathode follower between the tuned circuit and the grid of one of the oscillator triodes. The tubes used were a developmental type (Z-1383) which were built to posses a high degree of sturdiness and mechanical stability. A 7" diameter brass tube was used as a shield to minimize the effect of external disturbances.

To test the equipment, the frequency was set at 5 Mc with an ordinary tuned circuit, and the beat between it and the crystal frequency standards noted. When the plate voltage was raised from 225 to 325 volts, the beat frequency changed only 50 cycles per second. When the heater voltage was varied from 5 to 8 volts, the beat changed only 25 cps. This degree of stability was adequate.

The final technique for measuring coefficients of inductance used the tuned circuit shown. The oscillator was beat against the crystal-controlled frequency standard, the best frequency being measured by an oscilloscope and audio oscillator. As the temperature was varied, the beat frequency was measured and recorded. The change in the beat frequency was plotted vs. temperature. The slope (K) of this curve was calculated in ppm per deg. C. The coefficient of inductance of the test inductor was then:

$$\alpha = -2K$$

Capacitors C1 and C2 were zero-temperature-coefficient Ceramicons; C3 is tank capacitor.

B Supply: +150 v regulated.

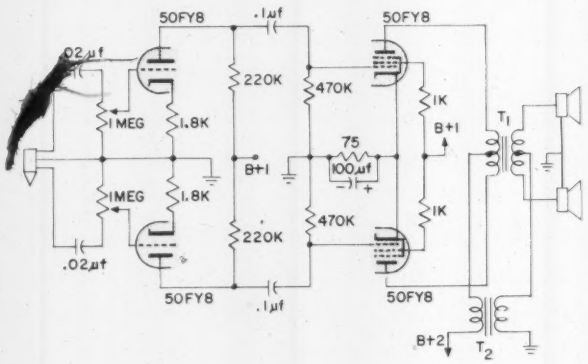
A Supply: 6.3 v ac regulated.

Source: Fred E. Dickey, General Electric Co., "Investigation of Temperature Coefficient of Inductance of Coils and Inductors," *Instruments & Automation*, April, 1955.

STEREO AMPLIFIER USES NEW PENTODE-TRIODE TUBE

This amplifier circuit develops 7 watts output to drive two speakers from the output of a stereophonic-record cartridge. Two CBS-type 50FY8 tubes are used; this new type has a power pentode and a high-mu triode in a single envelope.

Known as the CBS-Simplex circuit, the amplifier handles both channels of the stereophonic recording in a single amplifier. The "major" component of the total stereo signal is derived from the lateral motion of the stylus on the record, and is amplified in push-pull. It



CIRCUITRY

CHARLES F. KEZER

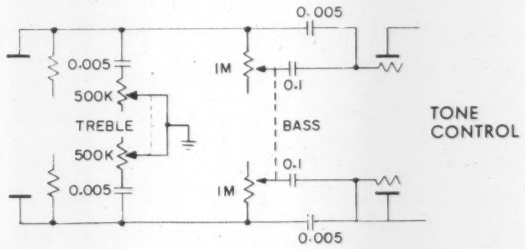
and

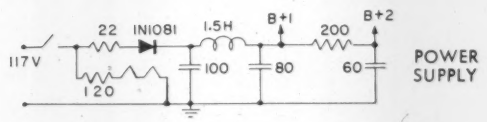
MILTON H. ARONSON

supplies the main power and qualities of both stereo channels. The "minor" component is handled as an in-phase signal, present on both input grids; it is derived from vertical stylus motion.

At the output, the in-phase signal developed by the two output tubes appears at transformer T2, and is combined with the push-pull output at transformer T1 at the speakers. Correct phasing must be maintained in order for the two speakers to produce the proper "Right" and "Left" outputs.

Tone controls can be added between the input and output stages as shown.





As the 50FY8 tube operates with plate and screen potentials as low as 125 v, no power transformer is needed. Heaters operate at 50 v, and are connected in series with a dropping resistor (120 ohms) across the line. A silicon diode is used as rectifier. To avoid shock hazard, power supply is not grounded to the chassis.

Circuit was developed for use with Columbia SC-2 and SC-8 cartridges; it cannot be used with other 3-terminal cartridges, but can be used with 4-terminal cartridges by reversing connections to one side to obtain proper phasing.

Input: Ceramic-type cartridge 300 mv. Output: 7 watts into two 4-ohm speakers. Distortion: 10% at full output. Hum and noise: 42 db below full output. Frequency Response: 3db down at 60 and 20,000 cps.

Source: J. Augeri and D. Christiansen CBS Electronics, Danvers, Mass.; also *Electronics World*, September 1959.

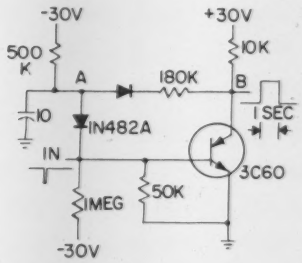
ONE-SHOT MULTIVIBRATOR USES NEW PNPN TRIGISTOR

The Silicon Trigistor (triggered bistable transistor) is a bistable semiconductor which has a unique property—it can be triggered on or off by a pulse applied at its base. It is particularly suited to memory, counting, timing and pulse applications.

The 3C60 semiconductor in this circuit is turned on by a positive pulse applied to its base; once turned on, it remains on until turned off by applying a negative pulse to either base or collector.

Delay time of the circuit is 1 second; by increasing the value of the 10-uf timing capacitor, up to 10 seconds delay can be obtained. When power is initially applied, the 10-uf timing capacitor charges positively until the 1N482A diode conducts, applying positive voltage to the base. This turns the 3C60 on, and its collector potential drops to 1 v. The Trigistor remains conducting, and the capacitor voltage decays to —11 v, as determined by the voltage divider made up of the 180K and 500K resistors, with the drop of the 5-v zener diode (1N469) taken into account.

When a —5 v trigger is applied to the base, the 3C60 cuts off, and its collector potential rises to 28 v. The 10-uf



capacitor begins to charge logarithmically (through the zener diode) toward +10 v (the voltage which point A would assume if capacitor and 1N482A diode were disconnected). In about one second, the voltage across the capacitor is near zero volts, the 1N482A diode becomes conducting, and the base of the 3C60 is pulled positive, ending the timing cycle. When the 3C60 conducts, its collector voltage drops to 1 v, and capacitor voltage decays toward —11 v. Circuit recovery time for recycling operation is slow because the capacitor must discharge through practically the same resistance (total) as during the timing cycle. Furthermore, it only approaches —11 v as a limit; recovery time is 4-5 seconds.

The 1-megohm—50K voltage divider at the base provide a base bias of —1.5 v for stable operation during the off period.

Input: Negative-going trigger, 5-v amplitude, 20-us wide.

Output: Positive-going gate, 27 v amplitude, 0.4-us rise and fall times.

Duration: 1 sec nominal. Timing accuracy depends primarily on stability of timing capacitor and supply voltage; Trigistor characteristics have only a small effect.

Recovery time: 4-5 sec est.

Power supply: + 30 v at 4 ma;
— 30 v at 30 ua.

Source: J. B. Hangstefer and L. H. Dixon Jr., Solid State Products, Inc., Salem, Mass.; also *Electronics*, Aug. 28, 1959.

Process Control Systems

FRED D. MARTON, Instruments Publishing Company

AUTOMATIC ACID PACKAGING MACHINE USES DIP-TUBE LEVEL CONTROL SYSTEM

This simple level control system speeds production in an acid packaging machine. It solves the problem of continuous filling of containers with a highly corrosive strength of sulfuric acid.

Basic principle of the filling operation is to maintain a constant head in an acid storage tank from which a hose drains acid for a predetermined time. With a fixed head and constant area for flow, the quantity can be accurately controlled on the basis of time. Acid stored in a shallow tank (12″ high) feeds into a series of rubber hoses arranged on a circular table under the tank. As the table rotates a hose to the filling position, a pinch valve on the one hose is tripped automatically to open for a predetermined length of time. The acid flows into 1½ quart polyethylene containers which pass under the hose on a conveyor belt.

Level control is provided by a low-cost controller. Basically a pressure measuring device, the controller utilizes back pressure in an air purge system to measure hydrostatic head as a measure of tank level. It incorporates pneumatic proportional control to position a pneumatic-operated valve on the inlet acid line, thereby maintaining a fixed head (10″) in the storage tank.

Level is measured by the air purge method. A regulated flow of air bubbles from dip tube E. At constant flow rate, the back pressure (static downstream pressure) is a direct measure of fluid head. The controller has a pressure element comprising a diaphragm capsule of phosphor bronze for high sensitivity at the low pressures involved. It has 1 to 100% proportional band with manual reset.

The indicating controller pneumatically positions the control valve through spring and diaphragm motor (2). The valve is 1″ size and is made from polyvinyl chloride to resist corrosion from the acid.

Plant air is first dried by one of two filters (A) arranged in parallel so that one can be regenerated by heating while the other is in service. From here the air line branches to furnish both controller air supply and air purge for the dip tube. Filter-Regulators (B) further filter the air and regulate it to 15 psi for the controller and the air purge system.

For the air purge system, a differential relay (D) maintains a constant differential pressure of 3 psi across a Rotameter flow meter (C), range 0.2 to 2 scfm of air. This permits steady air flow when the needle valve on the rotameter is adjusted so that the float is about mid-scale. A teefitting connects to both the dip tube in the tank and to the pressure element in the controller, Thus, back pressure due to hydrostatic head in the tank is measured by the controller.

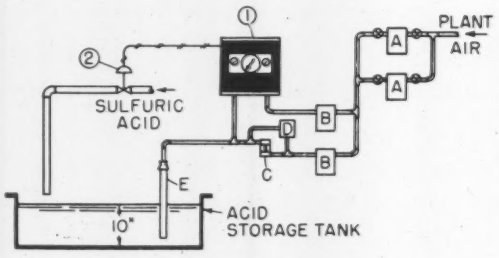


FIG 1

Instrumentation:

1. U. S. Gauge Indicating Pressure Controller with range 0-30″ H_2O and proportional pneumatic control, 0-100%.

2. Conoflow HB-11 Pneumatic Motor on Saunders Patent Diaphragm Valve (Valve Body-Polyvinyl Chloride).

A. Hankison "Dehydro" Filters.

B. Conoflow "Airpack" Filter-Regulators.

C. Brooks Rotameter "Sho-Rate" Flow Meter (⅛″ tube).

D. Conoflow Differential Pressure Relay.

E. Level measuring dip tube.

Source: U. S. Gauge Div., American Machine & Metals, Inc., Sellersville, Penna.

CHOCOLATE TEMPERING CYCLE CONTROL

Manufacture of good chocolate depends on the "tempering" stage of the process, which is vital in the elimination of bloom. This automatic control system solved some tough problems in measuring the actual temperature of the chocolate in the tempering kettle.

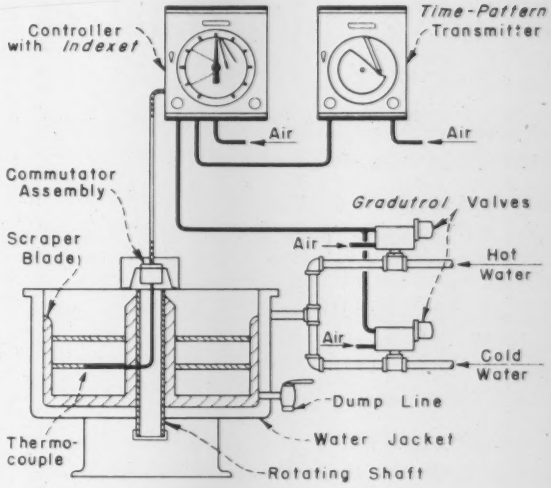
Basic variable is temperature of chocolate being stirred in the tempering kettle. Temperature of the kettle water jacket is maintained by admitting either hot or cold water via control valves on the hot and cold water lines.

The valves are controlled by an "ElectroniK" potentiometer-pyrometer with pneumatic controller (Type 152), equipped with remote set-point adjustment (Indexet), which receives its signal from a time-pattern transmitter (Type 802). The shape of the cam in this transmitter is determined by experience with the time-temperature processing cycle for the blend (usually a manufacturing secret).

Mode of control includes proportional and reset, resulting in accuracies better than $\pm 1/2$°F.

The pneumatic controller output signal adjusts two bellows-operated V-port valves (Gradutrol). These valves provide a characterized flow by means of a V-port inner valve which, combined with a toggle linkage, gives an equal-percentage change in flow for an equal increase in control air pressure. A relay built into the power unit provides positive positioning.

The thermocouple is mounted on the agitator arm and the leads are brought through the rotating shaft by a commutator-type switch. As the arm moves



throughout the kettle volume, a good average temperature is obtained.

Primary element is an I-C thermocouple with a stainless-steel protecting tube made into an assembly with the special commutator switch.

Accurate control is assisted further by using constant-temperature hot-water and cold-water supplies.

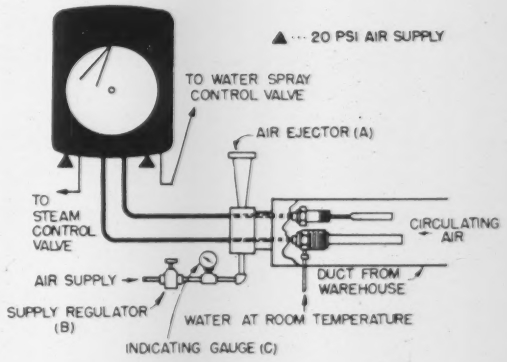
Source: Minneapolis-Honeywell Regulator Co., Brown Instruments Div., Philadelphia, Pa., also Instrumentation Data Sheet No. 3.3-2a.

NONHAZARDOUS HUMIDITY CONTROL FOR EXPLOSIVE ATMOSPHERES BY WET-AND-DRY BULB

For the control of humidity in explosive or dust-bearing atmosphers such as in ordnance plants or warehouses, grain mills, etc., a wet-and-dry-bulb system can be used which does not require explosion-proof equipment.

The method illustrated employs a Foxboro Model 40 pneumatic Wet and Dry Bulb Recorder-Controller, which essentially is a recording psychrometer equipped with a dual control system. The wet-bulb control system is related to humidity, the separate dry-bulb system to room temperature. The instrument has a mechanical chart drive to avoid possible sparking. Mode of control is, in general, proportional only, with rate and reset available, depending on the process.

The primary elements are located in the duct going to the warehouse in which the air circulates. The wet bulb is a standard Foxboro porous sleeve type, past which air is drawn by means of an ejector. Compressed air is fed to air ejector, through a regulator. The partial vacuum from the ejector creates the air circulation past the wet bulb. The regulator maintains a continuous flow of representative sample air past the wet bulb. The evaporation rate is related to the humidity of the room.



The wet-bulb control system sends a pneumatic signal to the water spray control valve, which is single-seated for tight shutoff. The signal emanating from the temperature control system positions a valve in the steam line which furnishes the heat. This valve is also single-seated for accurate control and tight shutoff.

Source: The Foxboro Co., Foxboro, Mass.; also Application Engineering Data 000.14.

Chalmer E. Jones **discusses**

The fast evolving status of the On-line Process Computer

Three years ago it was not considered feasible to apply digital computers to on-line plant operations because of the technological barriers involved with circuit and component reliability. Now, rather suddenly, industry is faced with the availability of computer systems that not only meet, but surpass previous industrial reliability standards.

The availability of this powerful tool is presenting an absorbing challenge to industry. Most major, and many smaller, companies have active programs underway directed toward the implementation of these computer systems.

Parallel to the remarkable achievements gained in reliability have been substantial cost reductions through advanced circuit design and production engineering. A concrete example of this is the Daystrom solid-state, magnetic core memory computer which is priced at less than half that of one of the most widely used business and scientific machines of equivalent capacity. To fully appreciate this comparison, it should be noted that the compared machine is of the vacuum tube rotating drum type.

This reduction in cost has brought the computer system into the area of data logging. The fact is, that computer systems are now competitive with high quality data loggers on average size jobs, and are substantially lower in cost on large jobs. This, plus the tremendous functional advantages of computational ability and flexibility through internal programming, suggests that computer systems will be the data logging equipment on all but the simplest applications.

The steps toward wide application of on-line computer systems are rapidly becoming defined. Since these systems are ideally suited for sophisticated data reduction and logging, this application is a logical first step.

Users are realizing that on-line computer systems, although basically designed for on-line process control, actually serve two other fundamental functions: reduction and logging of operating data, and reduction of evolutionary data for the purpose of developing the mathematical models necessary to apply the equipment to actual process control.

Stated differently, the same identical equipment is functionally self-evolutionary. At the start, the mere attainment of operating guides, such as heat and material balances on a minute-to-minute basis, provides tighter control of operating conditions. While this type of operation falls under the general heading of data logging, it should be recognized that the computer provides reduction of the measured data to terms more meaningful than the simple tabulation of pressures, temperatures, flows, etc.

The next step in the utilization of this equipment is the investigation of the kinetics of the process. Since

CHALMER E. JONES, GENERAL MANAGER,
DAYSTROM SYSTEMS DIVISION OF DAYSTROM, INC.

the computer is internally programmed, it is completely flexible in its functional operations. Reserve memory capacity, for example, may be experimentally reprogrammed on a day-to-day basis in order to determine correlations and dynamic behavior.

The on-line computer system, therefore, serves as a powerful tool in overall systems analysis leading to the formulation of partial or complete mathematical models of the process in question. It is perfectly feasible to start implementing actual computer control on a partial basis as operating parameters are established. The final and third step is, of course, the full use of the computer system for overall control of the process.

On the basis of orders and field operating experience, Daystrom Systems presently leads the field in the application of computers to on-line plant operation. The availability of these new techniques and associated equipment are receiving careful study by most leading companies. Our specialized systems engineering staff is organized to give your problems individual attention. Write or telephone Daystrom Systems, Dept. A-130, Miramar Rd., La Jolla, California. GLencourt 4-0421.

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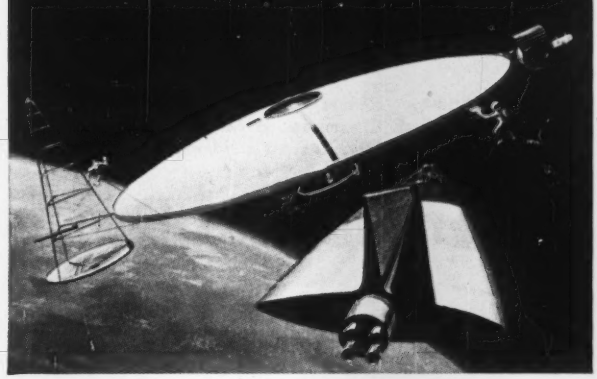
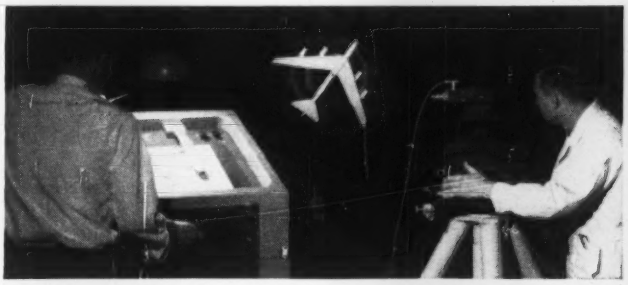
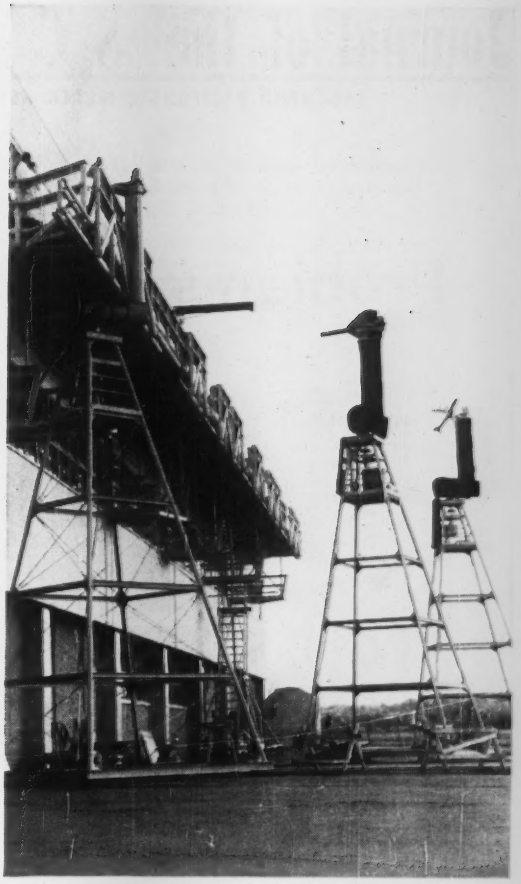


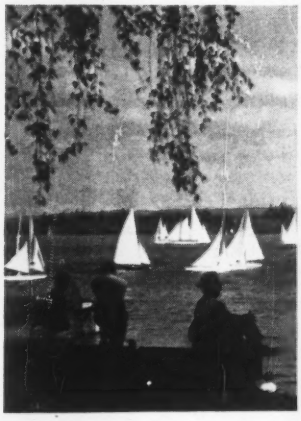
MARS VEHICLE. Drawing, based on Boeing study, of space vehicle designed for launching from orbiting platform for reconnaissance flight to Mars and return. Lunar, orbital and interplanetary system studies, and expanding programs such as the advanced Minuteman solid-propellant ICBM, are typical of challenging, long-range assignments Boeing offers electronic-electrical engineers.



DARK TUNNEL. View in 100-foot dark tunnel, part of extensive Boeing infrared research and development facilities. Boeing investigations include use of infrared, visible and ultra-violet techniques for use in communication, navigation, detection and guidance at altitudes above tropopause. IR systems, inertial navigation, electrical power systems for satellites, shockwave radiation and refraction and irdome heating are other areas of assignments open at Boeing.



ANTENNA PATTERN RANGE, with movable towers capable of handling models up to 1000 pounds. Boeing has openings in ECM antenna development, and in gas, solid and liquid dielectric research, as well as large-aperture antennas for ASMs, orbital vehicles and airborne warning systems. Other openings are available in instrumentation, missile guidance and control.



SEATTLE area, boating capital of U.S., offers world-famous recreational facilities. Fresh and salt water boating and fishing are only one hour from dramatic snow-capped mountains renowned for six-months-a-year skiing. Mild year-round climate. Excellent schools and universities, cultural activities, modern housing and shopping centers. Wonderful Western living for the whole family!

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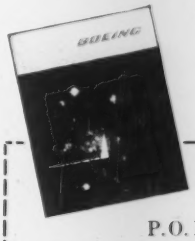

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Problems and Answers in the Design

These twelve questions arise often during the discussion and design of closed-loop computer control systems. They involve theory and technique, dollars and practice.

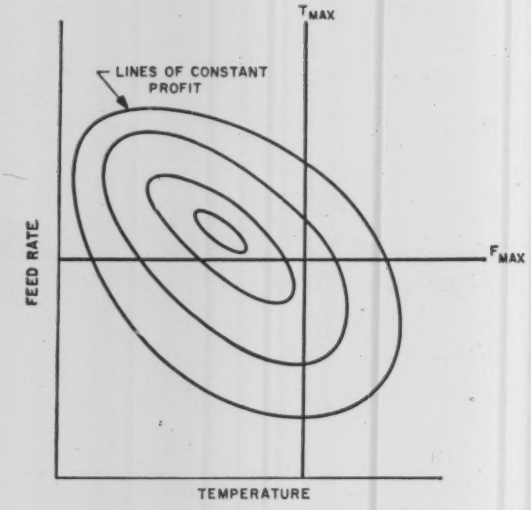

FIG. 1. EACH circular line connects combinations of feed rate and temperature that result in equal profit. Here the constraints shown of a maximum permissable feed rate and temperature restrict profit below its optimum.

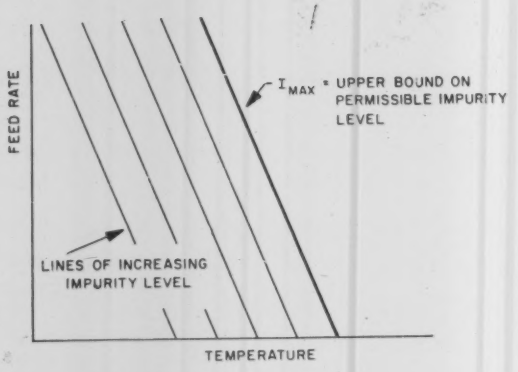

FIG. 2. EACH line connects the combination of input variables that results in equal impurity level.

Question 1: How Do You Optimize Plant Performance?

There are three general steps in optimizing a process:

1. Establish objectives.
2. Express objectives in terms of dollars and process variables.
3. Maximize the profit.

Establish Objectives

While establishing process objectives may seem elementary, it warrants much thought. Optimization objectives often are not clearly formulated or fully agreed upon by plant personnel at the beginning of an optimization study.

Typical objectives might be maximum production, quality control, minimum cost, or perhaps combinations. Whatever goal is desired, it must be stated in simple, unequivocal terms.

Express the Objectives in Terms of Dollars and Process Variables.

Once the objectives are established they must be expressed in terms of dollars. A profitability expression states that:

Profitability = Value of Products
— Value of Raw Materials
— Proportional Operating Costs
— Fixed Costs

Relationships between products and raw materials and the process operating variables must be established. This can take from several months to a year or more.

The problem to be solved is the maximization of the profitability, subject to the relationships between the variables and various constraints on such items as quality, flow rate, etc. When the profitability ex-

January Meeting: Thursday, the 21st, Rio Hondo Country Club, Downey, Calif.
Feature: Mass Flow Measurement by Robert Siev, Aerojet-General.

# of Computer Control Systems

S. M. ROBERTS

T. M. STOUT

The Thompson-Ramo-Wooldridge Products Company

pression is maximized, the quality, flow rate, pressures, etc., are determined at this maximum. A computer then can send signals to the various controllers to set all set points at these specified flow rates, pressures and temperatures.

Question 2: How is the Profitability Expression Maximized?

A number of mathematical tools are available for maximizing, including differential calculus, linear programming, non-linear programming, dynamic programming, gradient method, and calculus of variations.

Differential Calculus

The most obvious way to locate a stationary maximum or minimum point is to use differential calculus. Differential calculus has been found to be a useful optimizing tool. The profitability expression is differentiated with respect to each variable and the derivative is set equal to zero. The set of "n" equations for "n" variables is solved simultaneously for the pressure, temperature, flow rate, etc., which correspond to conditions that yield a maximum profit. This method of differential calculus locates the stationary point for the general case.

Where there are restrictions on the variables, such as an upper limit on flow rate, and upper and lower bounds on temperature, the optimum might not lie in the admissible region. What we must find, generally, is the *sub-optimum which corresponds to reality.*

As long as the function is relatively simple, a sketch of the response (profit) surface will locate the relative position of the optimum and the operating constraints. For example, in Fig. 1 the feed rate is plotted as a function of temperature. This gives contours of constant profit with the limits on feed rate and temperature shown. The admissible region here does not include the optimum as determined by differential calculus.

Sometimes complex functions have been represented by superimposing contour lines of constant composition, pressure, etc., on the profit contour plot to determine the admissible region. For example, in Fig. 2 lines of constant product purity are plotted as a function of feed rate and temperature. Fig. 3 is a composite of Figs. 2 and 1. Here the optimum operating point is limited due to the constraints.

Linear Programming

Linear programming has been used when a linear relationship exists among the variables, and when the objective (profit or cost) is a linear function of the variables. The technique is particularly useful for large blending or mixing problems where it is desired to choose raw materials out of a wide selection of possible sources to meet product specifications at a minimum cost.

A linear-programming problem consists of a set of linear inequalities and an objective equation to be maximized or minimized. The inequalities are converted to equalities by the mathematical device of introducing "slack variables." For example, in a blending problem in the cement industry, the alkali content of the product may be required to be less than 0.5%. When the alkali balance is set up, a slack variable is introduced to convert the inequality to an equality. When the problem is solved, the slack variable for alkali will have a value ranging anywhere from 0 to 0.5%.

A characteristic of linear-programming problems is the fact that there are more variables (m) than equations (n). Since n equations can be solved for only n variables, the linear-programming techniques picks out of the total of m variables, the n variables which satisfy the n equations, and optimizes the objective equation. The existence of more variables than equations arises from the fact that many raw materials may be considered to meet a limited number of requirements, and also from the introduction of slack variables to convert inequalities to equalities.

For computational purposes a very efficient numerical method, the *simplex algorithm*, is available. This procedure guarantees that an optimal solution will be obtained in a finite number of steps.

Linear programming has been found to be a useful approach in a variety of problems.

Non-linear Programming

The field of non-linear programming is still in its infancy. The power of linear programming is based

on the fact that sets of linear equations are fairly tractable to mathematical analysis. The inherent difficulty with non-linear programming is that non-linear equations are difficult to solve. When thrust into the complexities of inequalities with an objective to be optimized, the non-linear system becomes even more difficult to resolve. For large non-linear systems, the most reasonable approach at this time is to linearize them, if possible, and then use linear programming.

Dynamic Programming

Dynamic programming also is a new field of mathematics which should be useful in optimizing processes for computer control. It embraces the area of multi-stage decision making. For example, in a chemical plant, catalyst replacement can be considered a multi-stage decision problem. The decision to be made each day is whether to keep or replace the catalyst. The multi-stage decision process must consider (1) the declining activity of the catalyst, (2) the cost of catalyst replacement, (3) the loss of earning power during the replacement period, and (4) the improvement after replacement.

Multi-stage processes can be solved either by the *combinatorial method* or by dynamic programming. The combinatorial method considers at the initial time all possible combinations of keeping or replacing the catalyst. This method is not practical even for machine computation because of the large number of combinations which must be considered. For example, in setting up the catalyst replacement problem for a normal 30-day period, 2^{30} combinations would have to be considered. Of course, experience might indicate that for the first 20 days of catalyst life the catalyst performs satisfactorily. The question of replacement then could be resolved by examining 2^{10} combinations.

The dynamic programming method solves the multi-stage problem by reducing it to a stage-by-stage process where only one decision is made at each stage. Recursion formulas are set up where the results of one day's decision can be expressed in terms of the next day's decision. We anticipate that dynamic programming will make important contributions to optimizing computer control.

Gradient Methods

Gradient methods of determining an optimum are based on investigating the *surface slope* in various directions from an operating point on a response (profit) surface, and then moving in the direction of the greatest change—i.e., the steepest ascent. At each new operating point, the direction of steepest ascent is re-assessed. At the optimum point the derivatives are of equal value in all directions.

The method described by G.E.P. Box and associates[2] in effect fits a first-order (or, at most, a second-order) surface to the true response surface in the neighborhood of the operating point. Box only considers a system in two variables and determines the response contours. A limit of two variables is not as restrictive as it may appear because these may be the result of complex groupings. A plotting of the response contours and the operating point on it gives a neat picture of the response surface and an orientation with respect to the optimum.

The gradient method will locate a local optimum. If the system should consist of two peaks, the gradient method will discover only the one nearest the operating point. However, in industrial problems more than one peak is rare.

The problem of handling constraints in the gradient method is resolved by differential-calculus techniques. If, in seeking an optimum, the operating point passes beyond the boundary, then the point must be constrained to move along the boundary to stay within the admissible region.

While the gradient method is still the subject of much research, we have found modifications of it to be a useful tool.

Calculus of Variations

The calculus of variations has been used by mathematicians to determine curves which minimize integrals. The problem in one dependent variable requires that:

$$\int_0^T F(t, y, y')\,dt$$

be minimized. The function $y(t)$ which minimizes the integral will be found from the solution of the Euler-LaGrange differential equation. The term y' is the derivative of y with respect to t. The general solution is found from:

$$\frac{d}{dt}\frac{\partial F}{\partial y'} - \frac{\partial F}{\partial y} - \left[\frac{\partial F}{\partial y'}\right]_0^T = 0$$

If the boundary conditions are chosen properly, the integration-by-parts term (in brackets) vanishes at the end points $t = 0$ and $t = T$, and only the Euler-La Grange equation (first two terms) remains. For multiple dependent variables, the function would be:

$$F(t, y_1, y_2, y_3, y_1', y_2', y_3')$$

and there would be a set of Euler-LaGrange equations, one for each variable y_1, y_2, y_3. The solution to this set gives all the variables as functions of time which would minimize the integral.

The calculus of variations can be used to optimize process control problems, provided the problem is skillfully formulated. The function $F(t, y, y')$ to be minimized over time is the cost equation. The total time of the integration is the length of a cycle, perhaps the time between catalyst changes. The y's may be feed rates, conversion, or temperature. The solution will tell how the feed rate (y_1), the conversion (y_2), and temperature (y_3), should vary with time over the life of the cycle to minimize the cost.

The method is extremely flexible. Both linear and non-linear functions can be handled. Both time-dependent and time-independent constraints can be considered. We have found the calculus of variations a useful technique.

Question 3: How Do You Know Which Optimizing Procedure to Use?

Sometimes there is an obvious choice; at other times the method of attack becomes a matter of personal

preference. In other cases it is difficult to find a single method, and combinations of methods can be employed.

In the case of linear systems with constraints, the linear programming technique would appear to be the obvious choice. However, in time-dependent processes where the results of today's performance influences tomorrow's operations, the linear programming method may not be the best.

While in principle the linear programming method can solve the problem, some practical aspects may preclude its use. For example, the size of the matrix can become so large that size of the computer memory and speed of solution become limiting factors. In a time-dependent linear program, the matrix for a single day's operation must be repeated for each day of the cycle. As a result, the over-all matrix for the cycle consists of a matrix for each day, an echelon (Fig. 4).

An alternative attack is setting up the problem for solution by calculus of variations. In this manner the solution also will appear as a function of time, but the problem size will be more or less independent of the number of days in the cycle.

Question 4: How is Catalyst Activity Decline Handled by the Optimization Problem?

For a chemical reactor process (where fouling of heat exchangers is not a severe problem) the only time-dependent element is catalyst activity. The optimization model must include the shape of the catalyst-activity time relationship to determine when to shut down the unit and reactivate the catalyst. The model must relate the length of the cycle, the number of cycles, and the loss of production during reactivation to over-all production and process objectives.

There are two general ways of estimating when to change the catalyst. The *a posteriori* method consists of plotting cumulative net dollar return against time and determining graphically the optimum value of profit/time (Fig. 5). Beyond this point, profitability declines.

The *a priori* method uses the calculus of variations. This technique consists in solving the problem for various cycle lengths and evaluating the profitability. The maximum profitability will be found for some cycle lengths; also the catalyst-activity/time and the corresponding-variable/time relationship will be found.

Question 5: How Precise Must the Mathematical Model Be?

Closed-loop computer control does not require that an extremely precise model be established. What is required is only a reasonably accurate representation of the process.

Of course the more precise the model the greater the economic possibilities. But to think in terms of a precise model means perhaps waiting until various types of commercial instruments are more highly developed or, even worse, waiting until some new, yet-to-be-seen, instrument is marketed. With the hardware and know-how available today, sufficiently accurate models can be achieved for money-making closed-loop control systems.

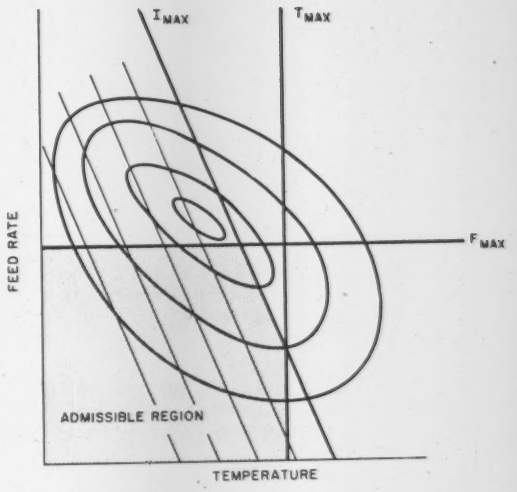

FIG. 3. DOTTED area is permissable operating region found by superimposing Fig. 2 on Fig. 1.

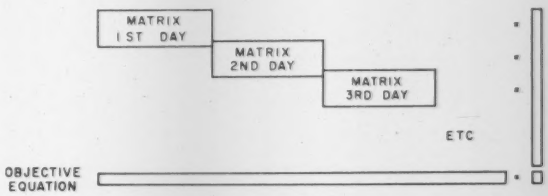

FIG. 4. SCHEMATIC diagram of time-dependent linear program shows sequence of daily matrixes combined into one large objective equation.

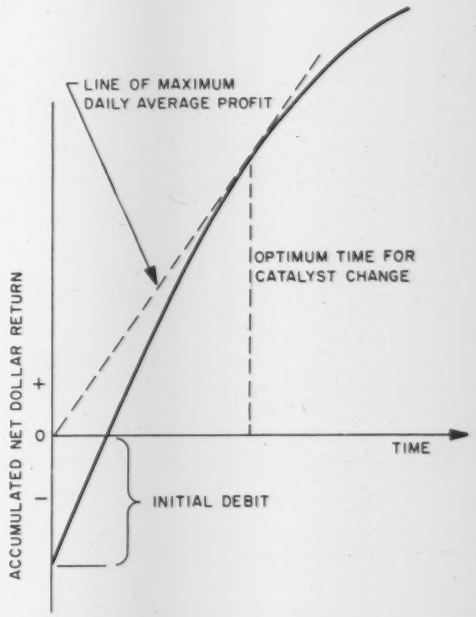

FIG. 5. POINT of tangency between total net return and line from origin reveals optimum life of catalyst.

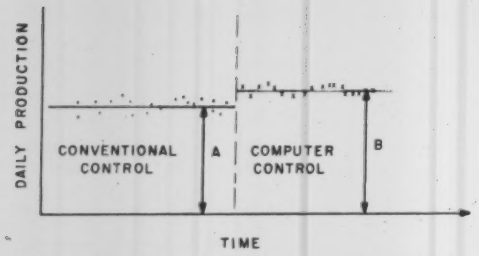

FIG. 6. DIFFERENCE between A and B is benefit of computer control. The validity of this difference can evaluated by statistical techniques.

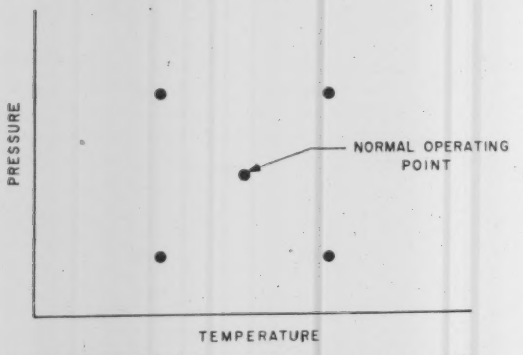

FIG. 7. FIVE-POINT evolutionary operation will reveal where to move the operating point to approach an optimum.

Question 6: If a Mathematical Model of the Process can be Developed, is Computer Control Necessary?

The prelude to successful control of a process is an adequate mathematical model, but the model is not enough. It must be implemented by putting into practice the rules of decision and operation specified by the model. The question really asks: Can computer control earn enough dollars above the best manual and conventional instrumentation to pay for itself?

There has been some discussion as to whether the effects of process improvements through computer control can be even measured. The argument runs that justification for control systems may be based on increasing throughput by say, 1 or 2%. Since the instruments are only accurate within 2 to 3%, how can the improvement, if any, be separated from the noise in the data?

Fig. 6 shows a daily production record before and after computer control. The fluctuations around the average are due to inaccuracies of measurements and to various uncontrolled variables affecting the process. Let us assume that the fluctuations around the average are of the same magnitude for both sets of data. We desire to know whether there is truly a difference between the average production before and after computer control. By statistics we can analyze the data and determine whether the values are significantly different.

Our experience has been that *even operating under the same set of rules of decision, the best operator cannot solve the equations, adjust the set points, and supervise the process as well as can a computer.* In point of fact, using a mathematical model, we set a process at its optimum conditions at the beginning of a week and then let an operator take over to see how well he would do. *Full-time optimization by a computer gave approximately twice the increase in production that the operator was able to achieve.*

Question 7: What Does the On-Line Computer Do That is Not Being Done Now?

Programmed into the on-line computer is a profitability expression. The computer predicts what the maximum profit can be (consistent with the constraints on the system), and then adjusts various set points to move the system towards the maximum profit. In contrast, current operating procedures concentrate on maintaining constant pressures, temperatures, or flow rates to assure steady plant operation.

With computer control the effects of uncontrollable variables, such as ambient air temperature, humidity, raw material quality, etc., can be compensated by adjusting the controllable variables faster and more consistently than with conventional control.

Question 8: How Do Off-Line Computers Fit Into Designing Process Control?

A necessary prerequisite to on-line control is a clear understanding of the process and the relationships between variables. The information and data required for an *engineering study* are not necessarily the desired information and data required for *process control.*

For example, an engineering study of a chemical reactor would yield the pressure, temperature, heat flux and conversion, all as a function of the reactor tube length. This information can be obtained from an off-line computer. From the engineering study, the outlet temperature may be developed as a function of feed rate, inlet-outlet pressure and conversion, and this curve-fitted information can be programmed on to the on-line computer. Then a simple criterion of reactor performance, such as exit temperature, or an analysis (chromatography, perhaps), is all that is required to control the reactor. In brief, the wealth of data available from off-line computer studies can be capsuled and used effectively by the on-line process computer.

Question 9: What About Dynamics?

The field of process dynamics is wide open for investigation. Our experience has been that changing set points of instruments by the computer every 15 to 20 minutes does not create any stability problems. From time to time, transient-response or frequency-response tests may be required to analyze the process dynamics. However, in one case, during a study of plant performance, we discovered that the process was marginally stable. A transient analysis disclosed that, with the existing instrumentation, about a seven-minute dead time existed in the process. An examination of the transfer functions also revealed one unit with a

particularly high gain. After some minor plant modifications, the transfer function of the process was altered enough to make the process stable.

Question 10: What Can We Learn From Plant Data?

Plant records can be valuable sources of information. When the log book is kept up to date, and when the supervisory and operating people are available to interpret the plant records, then the data take on significance.

From carefully kept records we can find the average and variance of production rate, feed rate, product quality, and other operating variables. From this can be estimated the potential production available and the cost of off-specification products. Also it may be possible to develop various transfer functions for plants which have dynamic problems.

In many processes the physical and chemical data are not available for prevailing plant conditions. Skillful use of the operating data can help fill in these blank spots. In particular, the kinetics of many processes are improperly understood. The data of plant reactor feed, products, and operating conditions can be used with a computer mathematical model of the process to aid in evaluating the rate-of-reaction equations.

A new and potentially powerful way to make the process produce useful information about itself while it continues to make product is the *evolutionary operation concept* of G.E.P. Box.[2] In this method the process is perturbed slightly from its normal operating point according to some predetermined experimental procedure. Fig. 7 shows how a five-point cycle can be used around the normal operating point in the center. Each combination of pressure and temperature is held for, say, a day's operation. By operating through this experimental cycle, knowledge of the process can be advanced daily without unduly upsetting production. Analysis of the data at the end of a number of cycles will reveal in which direction the normal operating point should move toward the optimum.

Question 11: How Do You Handle Automation of Plants Where the Analysis of Product Cannot Be Made Conveniently?

In some industries, especially those handling solids, certain more-or-less nebulous qualities, such as abrasion resistance or hardness, are measures of product quality. Generally some empirical tests are used, such as tumbling the solids for a period of time and screening. On the basis of a certain percentage above or below a certain screen size, the product quality is evaluated as satisfactory or unsatisfactory. These tests may take several hours per sample. In the meantime, the plant may be producing off-specification product. Upon obtaining a knowledge of the test results, several hours may pass before the results of appropriate changes in the set points are felt.

Our experience has been that sample preparations, such as drying the solids, can be speeded up substantially if necessary. In addition, since the tests are empirical, investigation and development of other types of tests are worthwhile avenues of approach.

Under some circumstances the characteristic of the product used for control purposes can be calculated from easily-made measurements. For example, in a chemical process the vapor composition from a separator has been used to control the reactor conversion. Under plant conditions it was not convenient to sample the vapor continuously. It was not possible to calculate the vapor composition using conventional data (equilibrium constants or vapor pressure) because contact time was not long enough for the vapor and liquid to reach equilibrium. Nevertheless, by a series of special tests, a set of psuedo-equilibrium constants were established for plant conditions so that vapor composition could be calculated.

Question 12: Do You Instrument a Plant Any Differently With On-Line Computer Control Than With Conventional Controls?

If a plant were designed with computer control as an integral part of the system, then this would undoubtedly affect the choice of instruments and instrumentation. We would prefer electronic or electric types of instruments. This would permit electric signals to be transmitted to and from the computer without the use of P/E or E/P transducers. However, most of our computer systems are in existing plants where pneumatic instruments are already installed. For these plants P/E and E/P transducers have been integrated with the computer successfully.

On-line computer control requires more cascade-type instrumentation than conventional control. This is a natural consequence of the computer adjusting set points to compensate for the uncontrollable variables. The fail-safe system must take care of the possibility of computer failure, as well as instrument failure. In such a case, the set points are left in their last position prior to failure. Provision also must be made for periods of manual control, such as during preventative maintenance and perhaps during plant start-up or shut-down.

Conclusions

Briefly, the steps in optimizing a process are (1) establish objectives, (2) express objectives in terms of dollars and process variables, (3) maximize profitability. Although the choice of the optimization scheme is not always clear cut, enough techniques are available to make a reasonable attack on many problems. The mathematical model need not be extremely precise. Living and working with the engineering and mathematical skills and the instrumentation currently available, on-line computer control has been found to be profitable.

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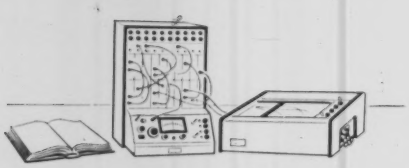

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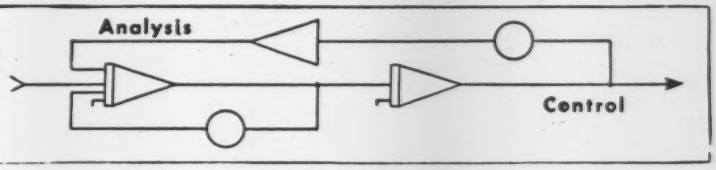

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Suzette McLeod, SECRETARY

8484 La Jolla Shores Drive,
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Bits

This month the *entire* Newsletter is devoted to a concentrated, expurgated, adulterated version of *P. J. Hermann's* very complete writeup of the June Midwestern Simulation Council meeting at WADC at which *Milt Warshawsky, Chuck Walli, Ken Cross,* and *M. E. McCoy* all told of their experiences concerning computer "bigness."

Pieces

MIDWESTERN S/C MEETING OF 8 JUNE ON COMPUTER INSTALLATION AND CHECKOUT

More than 110 people, from coast to coast and border to border, attended the 8 June 1959 meeting of the Midwestern Simulation Council at Wright Air Development Center in Ohio. Subject of the meeting was "Installation and Checkout of an Analog Computing Facility" with emphasis on large installations, and a particular feature was a demonstration of the new WADC-REAC and associated equipment in *Milt Warshawsky's* facility at WADC. And, the people saw a fine computer.

Milt opened the meeting, then turned the chair over to *Ralph King*, Vice-Chairman (Caterpillar Tractor Co., Peoria, Ill.). *P. J. Hermann* (Goodyear Aircraft Corp., Akron, Ohio), whose abstracted report of the meeting follows, says that particular posies should go to *Bob Harnett*, Milt Warshawsky's righthand man, and to *John Sansom* for the organization and execution of the meeting. Everything went off like clockwork; the regimented herding of the big crowd was such an excellent performance that for a while it seemed as if everyone was back in the Army, Navy, or Air Force.* Even the computer worked! For such a demonstration, astounding!

To get the meeting started Ralph introduced the Chief of the WADC Aeronautical Research Laboratory, *Col. E. C. Mallary***.

"I'm strictly a figurehead in this operation," Colonel Mallary said as he began a picture of the organization he was figurehead of. "The Air Force is one of the three major components of the Armed Forces. It is divided into Commands. The Air Research and Development Command is the youngest of these, having been formed in 1951-52. It's divided into centers—roughly a dozen of them—and this is one of them. This laboratory is the major component of this Center. Everything else is supposed to support the laboratory (though when you ask for support you sometimes wonder). Of 12 laboratories this is the only one involved purely in research. It's trite to say that its products are reports, but, that's basic research.

"The Engineering Analysis Division is part of this laboratory, and it is in this division that the analog computer is located. That's Milt's baby, and the labor pains were great! A normal baby was expected, but it turned out to be an elephant.* It is the largest integrated and the most versatile analog computer this side of the Iron Curtain. An excellent job has been done. The only reason it was late, and cost more than originally expected, is that the state of the art was exceeded. You will hear all about it in Milt's talk 'If I Had It To Do Over . . .'"

*!?

**Who, we understand, spoke with a fine, deep, Southern accent as befits a real Southern Colonel.

Warshawsky on "If I Had It To Do Over"

"This meeting today is, to us, a very important occasion," Milt began. "It marks a high point—perhaps a day of reckoning—in an effort that started over five years ago.

"As the Air Force's project engineer on this big computer, 'The System Dynamics Simulator,' I will try to give you an idea of what we hoped to achieve, how it was accomplished, and what we think of what we've got."

Milt then digressed to thank Colonel Mallary and those who helped with the many arrangements, particularly the machine demonstration, which caused him to add sagely that "the people of my branch can be

*What color?—Ed.

easily identified by their crossed fingers."

During the preceding year and a half, hundreds of visitors have seen the baby but couldn't appreciate it because they didn't understand the field. "I had the feeling," Milt said, "That all they took away with them was the fact that the machine was big, and pretty, and cost over three million—and I'm not even sure they remembered that it was big and pretty!

"Today we have the ideal combination; a finished machine and an audience of specialists in the field of analog computation."

Milt explained that his talk and the tour would emphasize operational features which make the WADC machine unique, but said that the audience should not forget that it is still just a large electronic differential analyzer, basically similar to the computers that many in the audience were familiar with. "Perhaps," Milt suggested, "I should start with the more standard statistics—the 36-24-36 type of thing."

The machine is large and split up into four identical stations plus a small central station. The stations may be used independently to handle medium-sized problems or in any combination of two, three, or all four. So far only one problem has used as many as three stations.

Each station requires two plugboards to accommodate the terminations of all its computing components. (An inventory of the components was handed out to those present.) **There is a total of 500 operational amplifiers available!**

Component Accuracy

A significant characteristic is that the installation is commonly called a 0.01% computer, which means that errors are supposed to be less than 10 MV. This 0.01% figure is a convenient, though somewhat fallacious, over-simplification. The summers and inverters actually showed average errors of 3 MV at 100 volts output, or 0.003%. The nonlinear elements do not permit referring to them as 0.01%, although they are in that ball park.

The diode electronic multipliers exhibit peak errors of 50 MV and less, are very stable as to calibration, and have many times the bandwidth of the servos. The accuracy of the diode function generators is difficult to talk about because no one has come up with a standard for defining it.

How Do You Know The Problem Is Correct?

Though the number of components is interesting, it is really the unique features of the WADC-REAC installation which set it apart. However, to fully appreciate them it is necessary to review the history of analog computing and simulation in earlier days. This Milt did in some detail, concluding that "The analog computers of 1954 left much to be desired, especially if you were seriously considering building one five times as large.

"People reporting past scientific advances tend to rationalize the rather hit-or-miss progress and try to show the overall grand strategy that was followed. In the case of this computer we can truthfully say that there was a grand strategy—planned before the contract was let—and adhered to until this day.

"Our principal objective was to build a large computer which produced accurate solutions to the problems we thought we were solving. 'Accurate solutions' obviously involved high-quality components. Not so obviously, they also involved means for insuring that the computer was being used in its optimum range as to frequency and voltage. Thus *time-scale check* and *minimum excursion indicators* were born, as well as capacitor check.

"As to really solving the problem you think you're solving, just think of some of the ways you can put a problem on the machine that isn't the one you intended to solve. You can:

1. Make an error in the mathematical manipulations of the original problem.
2. Make an error in the schematic diagram.
3. Make an error in wiring the board.
4. Wire in a non- or malfunctioning component.
5. Set a scale-factor pot wrong.
6. Set a function in wrong.
7. Forget to turn a switch.

And you thus get a correct solution to the wrong problem. It is practically impossible to prevent such errors, for as Steig puts it, 'People are no dammed good.' Our effort was directed toward making the detection of such mistakes not only possible, but convenient.

"Problem check, the patchboard verifier, automatically-set diode function generators, the whole Flexowriter system, all help to insure that the problem on the computer is one you want to solve.

"*Time scale check* is a rather simple idea that enables the operator to tell when errors are introduced into the solution by exceeding the frequency or rate capabilities of any computer components. Throwing a single switch causes each integrator capacitor of a station to be paralleled by another of equal value. This doubles the time constant of each integrator so that for any given input the output will vary at one-half its normal rate. In half speed the solution should be identical to that obtained in normal operation.

The *minimum excursion indicators* help with the scaling problem. Other computers indicate overload when voltages are too high. These MEI's are underload indicators, in that they remain on until that element's output exceeds plus or minus some preselected voltage, at which time they go out and remain out.

Capacitor check is to assure that all integrators integrate at the correct rate. When the capacitor check button is pushed, each integrator, with all other inputs removed, is fed a common voltage for a specified time, after which the station goes into hold. The absolute magnitude of each integrator's output is a sensitive measure of its performance.

Problem check is a powerful static test that tells almost everything about the problem setup on the computer, back to the original equations. However, before it can be used some desk calculation must be done. The operator assigns arbitrary values to all quantities existing at the outputs of integrators and from this computes voltage levels throughout the setup, using—insofar as possible—the original equations. Problem check is applied without disturbing the computer setup in any way.

Reflection on this test will reveal that in order to pass, the schematic diagram must represent the given problem, the wiring must be right, the gains of each element must be correct, the pots must be set right, arbitrary functions must be correct and, of course, each element must be operating properly.

"Problem check has proven itself forcefully in every problem we've handled since opening for business. I would go so far as to

say that any large analog computer requires this feature or its equivalent."

The *patchboard verifier* detects wiring errors. The wired plugboard is mounted on the verifier, which scans it rather rapidly. The output is a printed list showing every interconnection made by the patchboards, and open or shorted cords are indicated. The list is compared with the schematic diagram, and also serves as a means of problem storage.

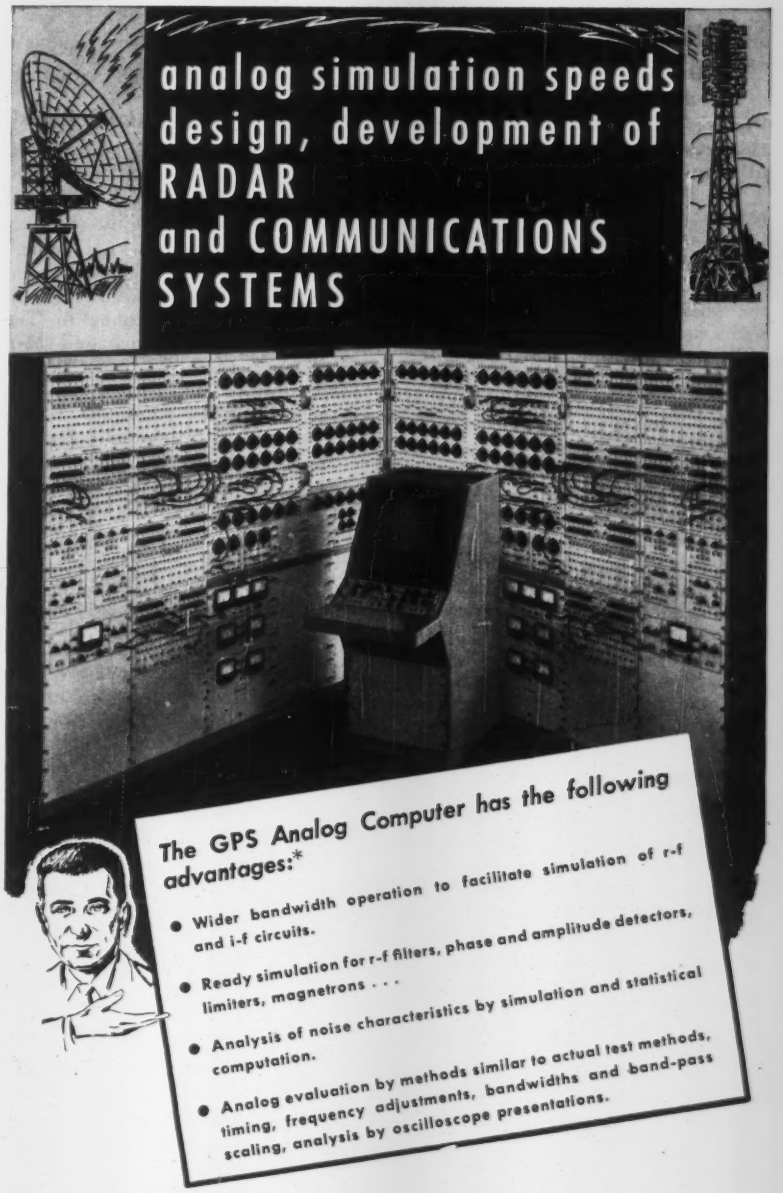
The *servo-set diode function generators* are probably the most interesting and exasperating components on the machine. When they are working properly they will set up a ten-segment arbitrary function in about two minutes—to a much higher degree of accuracy than could ever be achieved by the old hand methods.

"Although I've included these automatic DFG's in the list of items intended to insure the validity of the problem setup—which they do to a degree—their main value lies in their speed and accuracy of setup which permit rapid problem changeover. The generators are set up at the command of the Flexowriter or a coded punched tape, requiring only the x-y coordinates of the breakpoints as inputs. However, the fiendishly complex logic and hardware involved in the apparently simple job of servo-setting the 10 slope, 10 breakpoint pots would make an interesting paper in itself. As a result, if an evaluation of the DFG's had to be made now, they would fare poorly because of their questionably reliability. We hope to improve them by further work, but right now we undoubtedly have the most expensive straight-line segments anywhere.

"The *Flexowriter system* sets the DFG's, the scale factor and problem check pots, reads and types out all computer component outputs (including these pots), automatically programs the computer through a series of runs, and changes parameters between runs. Instructions are given either at the keyboard of the Flexowriter or by means of a coded punched tape. The tape punch is an integral part of the Flexowriter.

"The Flexowriter system has several advantages over the old way of performing these operations. It's much faster, more precise, and less subject to error. Errors can still be made, but they can be detected because a typewritten record is produced of both the command and the result achieved.

"I've described some of the steps we took to insure the validity of the problem setup and the accuracy of solutions. Perhaps in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The GPS Analog Computer has the following advantages:*
• Wider bandwidth operation to facilitate simulation of r-f and i-f circuits.
• Ready simulation for r-f filters, phase and amplitude detectors, limiters, magnetrons . . .
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*The Defense Systems Department of General Electric, Syracuse, N. Y. selected the GPS Computer for their communication and radar optimization studies. By using analog techniques they propose to save considerable time and money by combining and compressing the stages of the development cycle.

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"In 1954 there were already in existence analog computers about as large—in the sense that they had as many computing components—as our new one. All these installations, with the possible exception of Typhoon, had something in common; they were built up by gathering together a group of small computers. Little consideration was given to the problems of bigness—the disproportionate increase in the possibility of errors as the size of the installation increases and the consequent need for more and conveniently applied built-in checks. Perhaps that is why Professor Murray, in 1953, publicly expressed doubt that any simulation involving more than 200 amplifiers could be successfully performed.

"There may be those among you who will disagree with our particular solutions to the problem of big computers, but I'm sure you will agree that there was such a problem and sympathize with our attempts to do something about it. One need only look at the current analog computer ads to see the general impact our computer has had on the industry.

"I closed a talk in Brussels in 1955 with this sentence: 'This machine is our way of expressing our confidence that electronic analog computers have a very important role to play and we hope that we have helped this infant science grow up.'

"Today I am more confident than ever that analog computers have an extremely important role, and that we have very definitely helped."

After this talk Milt showed slides of the checkout problem which had been run on the computer, a three-dimensional missile problem which was run twice, first on Stations 1 and 2 and then again on Stations 3 and 4. The slides showed three solutions: the new WADC-REAC solution (actual plotted results taken unretouched from the x-y plotters) with digital check points and Cyclone solutions superimposed. There were a few discrepancies between the digital and the WADC-REAC solutions, but they were minor. The Cyclone results compared favorably with the digital, and ordinary mortals would consider the checks to be remarkable. However, the accuracy of the WADC-REAC was shown to be phenomenal. Milt allowed as how this meant that the digital solution was, in this case, correct!

Walli on "The Best Laid Plans"

The second speaker was *C. R. (Chuck) Walli*, head of the Analog Computer Group at North American Aviation, Columbus, Ohio.

"I'd like to change my topic," Chuck began, "From 'Installing and Checking a Large New PACE Installation at NAA-Columbus' to 'The Best-Laid Plans of Mice and Men Often Go Astray'. We ordered four 231R consoles; thus far we have two of them, about 400 amplifiers. I want to discuss some of our difficulties."

Chuck, with the aid of a "check-out log" prepared at the scene, began to describe in detail a few of the many unexpected things that could and did happen from the time they lost track of the shipping van between the EAI plant and the NAA Columbus factories, through the installation trouble, to the early use of the equipment.

If we were to detail the tribulations of Chuck's saga here we would certainly discourage the more timorous who may be considering a similar installation. So, in deference to our friends who are also vendors (or vice versa) we will refrain.

However, the story has a happy ending. About the middle of March, after struggling with such things as factory doors which were too small to admit the computer, conduit holes bored in the wrong places, outside contractors and the company union (Chuck made the mistake of helping push the computer into position), loose wires, tubes that won't burn out (this was a well-planned job; they figured how many spare tubes they would need, ordered 400 of one kind —had used six in the first six months), a balky air conditioner, and miscellaneous human errors, they finally solved their first problem on the computer. Says Chuck, "The first problem that we put on the machine was a structures problem: the vibration modes of a rectangular wing. The people running it hadn't run a problem on an electronic analog computer at all before. One was just out of school, the other a civil engineer working in structures for a long time. The problem simulates a wing with a forced deflection at one point while it remains a flat plane everywhere else. We used 130 amplifiers; got RMS error of 0.06% relative to the IBM program results. The maximum error was 0.16% on any one term. We found that the frequency of the normal modes checked to 0.4%. Actually, on the first three frequencies, the first three modes, we were within 0.1%. Only in the high modes did we have any appreciable error."

After Chuck's talk Milt asked him what specific things he had done about the computer problems associated with "bigness."

"The checkout features," Chuck answered, "Automatic scan, problem check . . ."

"Do you have a problem check similar to the one I described?" Milt asked.

"Not quite. We don't replace the output of the integrators with a pot. Instead we put an initial condition on the integrator and scan everything; first one at a time and then in total."

"That's what I described as the 'initial condition check'."

"We also scan the summing junctions at the integrators, which gives the initial integrating rate. This is a very nice feature. We've found more errors this way than with any other check. We are very happy about this," said Chuck. "The high-speed printer makes troubleshooting much easier. We're thoroughly sold on it."

"Do you have anything like the capacitor check?" Milt asked.

"Yes, although it is actually a sine-wave oscillator check. We check the absolute value of the oscillator frequency. You could of course accomplish the same thing by using a precision timer."

Cross on Checkout Procedures

The third speaker was Ken Cross (Allison Div., General Motors Corp., Indianapolis, Ind.). His topic was "Checkout Procedures in Installing the Allison EASE Facility."

"We purchased an off-the-shelf computer, too. And Milt's remark about some people not appreciating the problems of computers," said Ken, "Brings to mind a tour by some visitors we had one day. We got all set to make our demonstration run, the operator pushed the wrong button, and all the lights began to flash. The visitors thought this was great!"

The Allison EASE computer was purchased in January of 1956. The original order was for 150 operational amplifiers operating from three control consoles, 80 servo-set diode function generators, 40 electronic multipliers, 12 servo multipliers, and four servo resolvers, a total of roughly 330 amplifiers.

"Probably the most unusual thing about this computer is the large amount of nonlinear equipment. It is used to make compressor maps and turbine maps by feeding the output of

SPEAKING WITH EASE®

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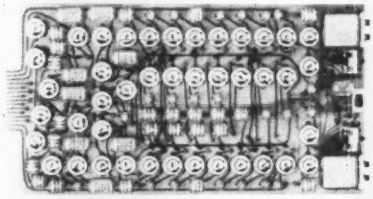
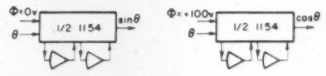
An Electronic Sine-Cosine Former for Fast Resolution

Capable of operating at output frequencies of 50 cps with less than 1% error, the new EASE Model 1154 removes the last major obstacle to solving non-linear problems at high computing speeds.



The Model 1154 consists of two identical computing channels, each mounted on the simple printed-circuit board shown above. Each channel will generate the sine or cosine of an input voltage when supplemented by two operational amplifiers. The circuitry consists of factory-adjusted diode networks. Output curves are formed from 22 line segments.



Diagrams above show how a computing channel in the 1154 may be connected with amplifiers and reference voltage (ø) to generate either sinθ or cosθ. The complete 1154 will thus generate both sine and cosine for use in resolution.

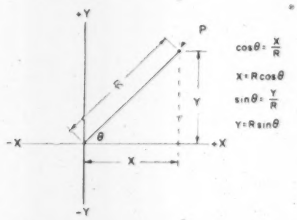
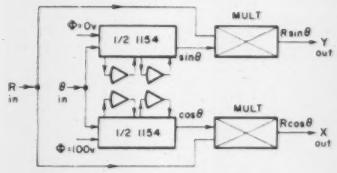
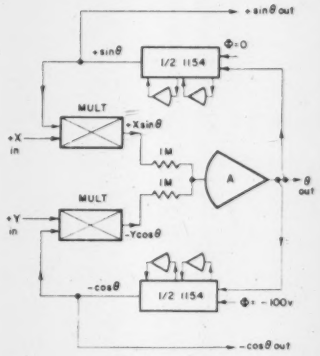


Diagram and formulae above show the elementary relations between polar and rectangular coordinate systems. As you will see following, the Model 1154 permits us to generate X, Y given R, θ and conversely to generate R, θ given X, Y. Coordinates may be generated continuously as point P moves through all four quadrants.



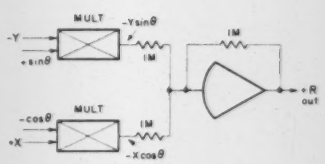
Hookup for forward resolution (i.e. transforming polar to rectangular coordinates) is shown above. An important advantage of electronic resolution is that the multipliers are free to generate non-trigonometric products when not used in a resolving circuit.



To accomplish inverse resolution (transforming rectangular to polar coordinates) we first generate θ using the feedback circuit diagramed above. Operation of this circuit is based on the relationship

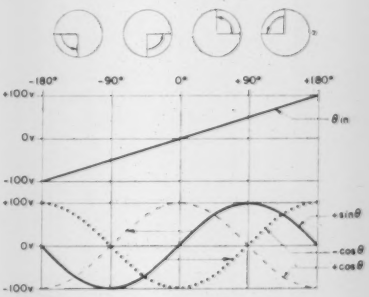
$$X\sin\theta - Y\cos\theta = 0$$

The output of amplifier A must be θ because only at that value will the outputs of the multipliers be equal and opposite in sign, thus producing the necessary net current of zero at the amplifier summing junction. Amplifier A is shunted by a .001μf capacitor to insure stability. Sinθ and cosθ outputs are used to generate R in the following circuit.

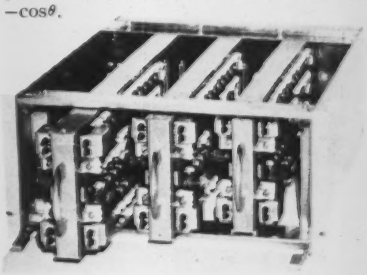


Operation of this circuit is based on the relationship

$$X\cos\theta + Y\sin\theta = R$$



Above is the transfer function of an 1154 channel. With ø input zero, the +sinθ curve is produced. This curve may be shifted $\pm 90°$ by applying a voltage at the ø input. Thus ø = +100v produces +cosθ; ø = −100v creates −cosθ.



Three 1154's (six channels) are shown in this 19" chassis. Ordinarily the chassis holds one 1154, four associated amplifiers and relays that form resolution circuits when actuated from the patchboard.

C11-1

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several function generators into the taps of a servo tapped-pot function generator, and taking the output of the map from the arm of the servo pot."

As Ken's group was anxious to get going, they did something unusual; they made arrangements to work on the computer at the Beckman/Berkeley plant before the computer was completed. When one control console had been completed, they sent two men to start setting up the first problem. They had check points already computed and checked a single-spool turbo-jet engine simulation component-by-component with compressor maps, turbine maps, and all.

Ken showed slides, and described the computer as well as a couple of tribulations: "We moved into a temporary setup. It was one of these six-month deals—'you'll be out of here in no time.' About a year-and-a-half later our building was completed and we moved again."

"We added trunk lines, about 80 of them, running from our computer laboratory to our central data recording center which is tied into our test stands, compressor rigs and burner rigs, and we didn't realize what we were getting into. But before long we were doing quite a bit of on-line data reduction. This tied up a lot of our equipment. But we had to put up with it because it gave the test stand operators a chance to actually see the results of their test while they were running it. This saved a lot of time."

There was also the usual quota of bugs in the computing equipment itself, but as the manufacturer has undoubtedly taken the Flit to these ere this, we will only mention four bugs which might have relatives elsewhere.

"We had some trouble with our electronic multipliers. We had purchased 40 of them, and found that when we were running our problems under certain operating conditions we had oscillations. We had a devil of a time with this one because we could change our conditions a little bit and the oscillations would go away. We finally determined that the electronic multipliers were set up in common chassis containing four units, two pairs on each side, and that there was coupling from one unit to another. Then it was only a matter of tin snips and wire to make a little shield down in there, and we haven't had any trouble of that kind since."

"Probably the most publicized troubles we had were with our servo-set diode function generators. We bought them, and they worked fine for a while. Then after a few months they started tightening up and the servos just couldn't drive them. We were immediately worried about the state-of-the-art business. But it turned out that it wasn't so much the state-of-the-art of the function generators as it was of nylon gears. They were not properly cured and were shrinking onto the ball bearings and holding tight. They were all replaced, gratis."

"It is possible to tie enough trunk lines onto the output of an amplifier to get quite a hunk of capacitance on there, and it can be enough to throw the amplifier into oscillation. We happened to stumble onto the solution, and it was quite easy. All we did was follow the amplifier with a common coefficient potentiometer and feed the arm of that potentiometer out along the line. That took care of it."

Probably the most incredible statement of the meeting was: "At the present time I can report that we have one technician. He's doing a bang-up job!"

And some good advice: "Always plan for expansion. When we first set up our facility we had three groups of components for our computer. The first group was what we thought we could get by with; it would be nice to have group number two; and group three was the cure-all.

When we bought group three we thought we had it. But in no time we needed more. That was the reason for buying the fourth unit. Then we found that to make the equipment a little easier to use we wanted to move around multipliers, etc. And so on to date."

McCoy on GEDA Checkout

The last speaker of the day was *M. E. McCoy* (Glenn Martin Co., Orlando, Florida), whose topic was "What We Did to Check Out the GEDA A-14 at Martin-Orlando."

"I'll have to tell you of a remark," McCoy said, "That I overheard in Ohio by a man who didn't know where I came from. 'Just what do you think of a company that wants you to go to work for $150 less just for some orange juice and sunshine?'

"The computer that I'll be talking about is the GEDA (rhymes with gee-dah) A-14. I will describe the delivery plan, the way in which the computer was divided into phases, construction of the phases, the problem of delivery, location and layout of the computer. I have a film that will show you how the computer was delivered, carried across the high-bay area and put into the second floor. Then I will enumerate our troubles during checkout, which I would classify as minor troubles. And I can mention a few major difficulties that developed after checkout or after acceptance.

"During the first and second quarter of 1957 *Frank Richmond* (Martin, Baltimore, Md.) was given responsibility for studying specifications for a computer to be located in Orlando and for receiving proposals and making recommendations. It was he who planned and steered the entire project until I came on the scene about June 1957.

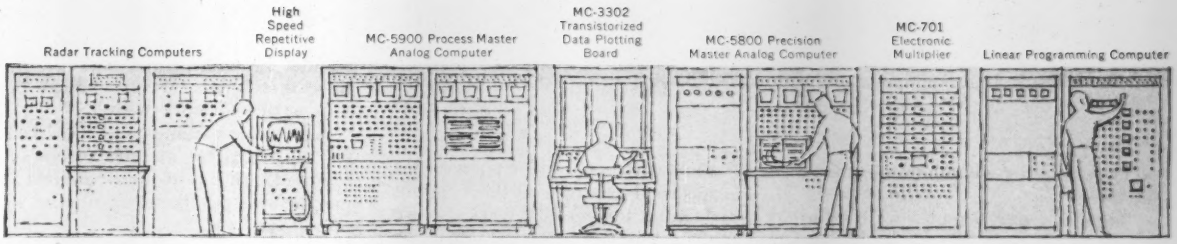
"Martin-Orlando had projects going and they needed computer facilities. The plan was to divide the computer into three phases so as to get us some computer as quickly as possible. Phase 1 was a 14-foot chassis which contained two computer subsystems. This to us means 60 operational amplifiers, associated nonlinear equipment and complete control circuitry for each sub-system, the equivalent of one patchboard. It had auto-set pots but manually-set function generators.

"Phase 2 was the same as Phase 1 except it was the final installation and had all the auto-set features.

"Phase 3 was only one computer, but it had a blank patch bay and the necessary racks for the expansion of one additional sub-system which would give us a total of 6. Phase 3 also included the DDT system, which is the automatic control and automatic programming feature.

"Phase 1 began operation in Akron during January 1958, was delivered in Orlando in February, and was in operation about four weeks after it arrived at the plant. Phases 2 and 3 and the automatic control system were demonstrated in Akron in May of 1958. All of our analog people spent a week at the Goodyear plant discussing the computer component by component with the design engineers and watching the computer in operation.

"It was clearly stated in the original agreement that supervision of installation, all wiring and necessary cabling and the checkout of the equipment were to be performed by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- EVERY SPECIFICATION IS GUARANTEED TO BE TRUE PERFORMANCE STANDARD—IN SUSTAINED OPERATION.
- Only diode function generators utilizing resistors, potentiometers, and diodes of equal quality to those in computing networks.
- Only diode function generators with individual hi-lo gain positions for *each* segment.
- Lowest function generator drift $<$ 5 mv/8 hrs.
- Lowest servo step-function overshoot—less than 1%.
- DC tachometer feedback on all servos.
- Complete control of all amplifiers, multipliers, dividers, and non-linear equipment at patchboard.
- Exclusive equipment-door packaging for free access and quick maintenance *without* shutdown.
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field service personnel of the manufacturer.

"Some of our troubles were eliminated by the way the computer was assembled, checked out in Akron, delivered, and handled. It was put on a skid when the racks were bolted together. This skid never left the cabinet until it was in place in Orlando.

"Our troubles were also reduced by the layout. All five of the computers, all interconnection, and all controls are in one cabinet. This means that for a 120-amplifier problem, on two boards, we require no interconnection between boards. I believe the maximum length of the patch leads is 27 inches.

"Troubles were reduced still further by having adequate well-filtered cooling air. However, if you have anything to do with planning air-conditioning equipment, do specify sealed ball bearings. One of our oilite bearings couldn't stand the load of the centrifugal fan, wore 3/8 of an inch, and deposited fine bronze dust throughout the entire computer, which had to be taken down module by module and cleaned before we could proceed.

"Our computer operates 24 hours a day, filaments and plates. We have found this necessary for the time-division multipliers.

"I also feel our troubles were reduced because we were interested in a good maintenance man. We didn't have a good one working for Martin-Orlando, so we contracted with the computer manufacturer to furnish the services of their best field service man for one year, and he helped us considerably."

Mr. McCoy showed a film (described by Bob Harnett as something of a paradox as it was a silent film in glorious Technicolor) on the delivery of the GEDA to the "Joe Jones Iron Works"* This was a hair-raising experience which involved lifting the computer intact 12 feet into the air and pushing it in through a hole in the second floor.

"I believe," said McCoy after the film, "That the troubles which developed after checkout could have been minimized had we defined our requirements better and paid closer attention to the specifications. Our resolvers, for example, were ordered for the fastest possible response, yet the specified accuracy of 0.3% is not satisfactory for missile work, so we have had to order much more precise resolvers.

"I would suggest that those who order a computer system define their particular requirements carefully. They will probably find that all the servo multipliers and resolvers need not be of the fast-response type but rather that some slow, highly accurate, and other fast, moderately accurate, ones would be better.

"Our electronic multipliers are the time-division type, and we have had to go through numerous training sessions with our maintenance people and operators to teach correct calibrating techniques. We have had to pay very close attention to uniform cabinet temperature, and yet they still give trouble when the variable goes through zero. And it's non-repeatable.

"We are also still having trouble with our patchboard terminals and leads. The dependence upon a nylon shoulder to spring out behind the board and form a holding device to insert the leads fully requires that they be checked very closely, because the nylon will take a set and let some patchboard terminals retract.

"We have also had some trouble with our digital voltmeter. It's a stepping switch type and the manufacturer had to come in and completely replace all the steps with ones having gold contacts.

"The automatic control system has worked very well and we're quite pleased with it. We have reduced the average re-insertion time for a 120-amplifier problem down to about 40 minutes."

Ed Massell (Electronic Associates Inc., Long Branch, N. J.) asked, "How fast and how accurately do you set the pots?"

"I don't know," McCoy answered at the time, but later wrote, "The correct answer is approximately six seconds times the percent of total pot length the arm must travel."

"You have an in-line computer," *Al Koeppel* (Standard Oil Company, Cleveland 15, Ohio) said. "Could you tell me how long it is and why you chose this layout instead of a U or some other shape?"

"The overall length of the computer is about 40 feet. We wanted an in-line computer because we thought it would reduce cooling and inter-cabinet grounding problems. We believe that it has. We also think that it is easier to work with."

Ken Cross commented, "I'd like to see the computer manufacturers supply hooks on top of their cabinets for people who put them up on the second floor."

Chuck McVey (Electronic Associates Inc., Mt. Prospect, Ill.) answered, "All I've got to say is, you should see pictures of Bob Kohr's trip through high-bay with our computer —on hooks. What did you think about that, Bob?".

Bob Kohr (General Motors Research, Detroit 2, Michigan) said that the 231R computers have tapped blocks accessible through the top. "We raised two of them about 40 feet in the air, but I had to go somewhere else while they were doing it."

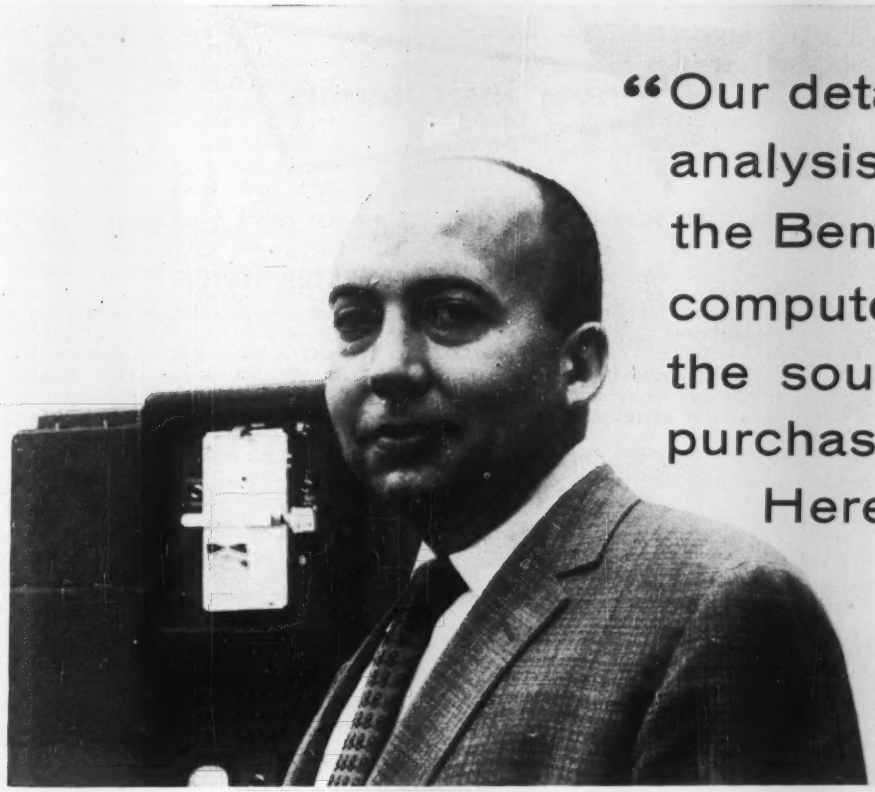
* * *

The afternoon was taken up entirely by demonstrations of about one hour each. *Bob Harnett* showed off the automatic pot set, problem check, capacitor check, servo function generator set, minimum excursion indicators, time scale change, the Flexowriter, and the solution of a three-degree-of-freedom problem involving escape capsule dynamics. The demonstration was especially impressive in that the automatic pot set could call for a setting of 40.0 volts and the DVM would show 40.01 volts. This kind of performance was consistent; even the auto-set diode function generator set to within 50 millivolts. Milt, Bob, and the boys had their fingers crossed, but it worked. Amazing as it might seem, not a single noticeable thing went wrong. Somehow the "demonstration effect" didn't become operative that afternoon.

The maintenance and repair setup is a grand automatized technician's room, obviously set up for volume and speed. Component checks are done with special semi-automatic units. And the patchboard verifier is a glorious automatic device which types out a list of the patchboard connections.

Summing up, P. J. says the facility that Milt is operating is certainly impressive. It's big, it's got all the bells and whistles, and if the organization on the day of the meeting is any indication, it's well run. But he, and he suspects others, left with the feeling that "This is a fine large machine, probably the best analog computer in the world. But was it worth the cost? Could not as good a machine have been obtained for less cost?"

*Mr. McCoy had been urged not to give too big a plug to the Martin Company.



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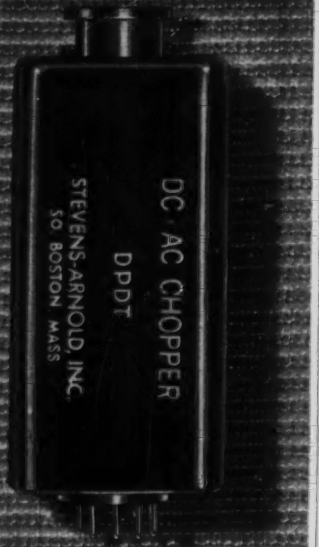

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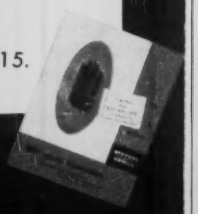

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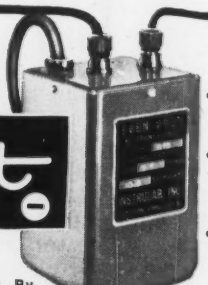

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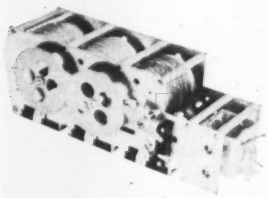
FEATURES
• **Eliminates** batteries ...errors due to battery exhaustion
• **Reliable** construction... from quality components, long, trouble-free service
• **A Precise** voltage regulator . . . max. ±.04% for ±20% voltage variation
• **Quickly Installed**... Fits present instrument battery space.
• **No Tubes** to replace

CIRCLE 71 ON READER-SERVICE CARD

MEM-O-TIZER A/D CONVERTER

"Mem-O-Tizer" is an An/Dig converter that provides readout up to 120 times per minute. Input shaft drives first-stage code drum. Additional drums, as required, are geared to the first drum. Each drum comprises a stack of wheels with periphery profiled by a series of high, intermediate and low faces. Solenoid-operated "sensors", each with a simple position-locking device, are in a row parallel to the drum axis and sense the drum profile. Each sensor closes one of two switches when it reads a high or low position. No switch closure occurs in the intermediate position.



A detent wheel on the drum has notches around its periphery. A detent pin advances into a notch to stop and accurately position the drum during the initial motion of the solenoid-operated sensors. All drums are sensed simultaneously. The sensors operate switches (that are locked into position) and are retracted in 0.050 second. No brushes or other electrical contacts are made or broken while the drum is rotating. Contact closure occurs only when the drum is stopped to be read.

The relay contacts are rated at one amp at 60 v dc. They provide direct compatible operation with any known business system, computer, or readout equipment, such as printer, visual indicator, adding machine, card punch tape punch, teletype and telemetry distributor.

Break-away torque of the single-drum (2-digit) model is 0.003 inch ounce. Torque of the two-drum (4-digit) and three-drum (6-digit) models are 0.004 inch ounce and 0.0043 inch ounce, respectively. Such minute drive requirements permit use in mechanical systems such as platform scales or dial gages with insignificant loading effect, retaining basic instrument accuracy.

The $\frac{3}{16}$" dia input shaft is connected to the main drum by a lost-motion coupler. This permits the detent pin to stop the drum for a reading while the input shaft keeps turning; when the drum is released the spring action of the coupler makes it catch up to the shaft. Such 'on-the-fly' readout is possible with the input shaft running up to 250 rpm.—*Automation Div., Telechrome Mfg. Corp., 26 Edison St., Amityville, L. I., N .Y.*

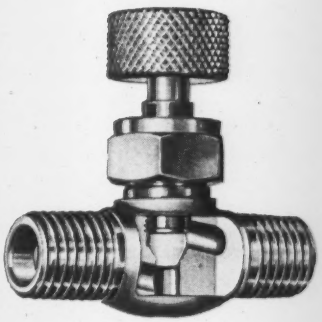
CIRCLE 174 ON READER-SERVICE CARD

These NEW Hoke Valves are leak-tight* FOR LIFE!

100 SERIES
General Purpose Valve for service to 10,000 psi

The O-ring stem seal design on this new, low-priced valve makes it permanently LEAK-TIGHT*. Use the 100 Series where you need an inexpensive, heavy duty valve for either pneumatic or hydraulic service. It's ideal for throttling, regulating, or shut-off applications over a temperature range of −40° to 200° F. Male or female connection and panel mounting, if needed.

- GUARANTEED leak-proof O-ring seal
- Exclusive nylon stem wiper
- Centerless ground stem
- Safe, integral bonnet
- Diecast aluminum handwheel
- Rugged, forged carbon steel body in globe or angle pattern



300 SERIES
Forged Needle Valve with Plastic Stem Tip

The same unique stem design used on the 100 Series, plus a new plastic stem tip, makes Hoke's 300 Series valve LEAK-TIGHT* for life at both stem and seat. Made of long wearing nylon or corrosion-resistant Kel-F, these plastic stem tips have taken twice the normal closing force through 700 cycles of operation at 3500 psi — with no sign of leakage across the seat! Available in brass or stainless steel bodies, for service to 3000 psi. Panel mounting, too.

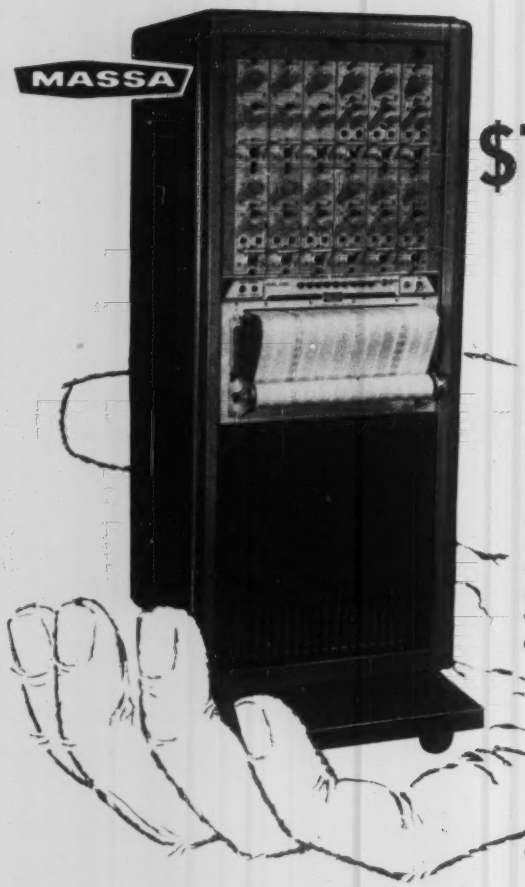
- Minimizes seat and stem point damage due to grit and over-torquing
- Provides vapor or vacuum leak-tight closure
- Minimizes opening pressure surges
- Service up to 3000 psi
- In ⅛" and ¼" pipe sizes and ¼" tube size

These are just two products in Hoke's extensive line of small, quality valves. If you would like our new Catalog GC959, or sample valves, write to us on your company letterhead.

HOKE

HOKE INCORPORATED
"Fluid Control Specialists"
31 PIERMONT RD., CRESSKILL, NEW JERSEY

CIRCLE 72 ON READER-SERVICE CARD



SAVE $10,000 EVERY 200 HOURS

WITH A MASSA 12 CHANNEL RECORDING SYSTEM. After operating only 200 hours at an average chart speed of 50 mm/sec, this direct ink writing system saves $10,000 in chart costs alone when compared to other systems with rectilinear readouts.

MODEL BSA-1200
WITH 12 PLUG-IN PREAMPLIFIERS
CABINET HEIGHT 62 INCHES

In this new system, Massa has combined all the advantages of rectilinear recording with the economy of ink writing. The result is a compact (50% more channels in a standard cabinet), reliable, and versatile recording system featuring a choice of interchangeable plug-in preamplifiers.

FEATURES

- CHOICE OF DC, AC, CARRIER OR CHOPPER PLUG-IN PREAMPLIFIERS.
- DC TO 200 CYCLES PER SECOND FREQUENCY RESPONSE.
- 18 SPEEDS — PUSH-BUTTON CONTROLS.
- INDIVIDUAL POWER SUPPLIES AND TRANSISTORIZED DRIVERS FOR EACH CHANNEL.
- INTERCHANGEABLE INK AND ELECTRIC STYLI.
- MODULAR DESIGN THROUGHOUT FOR EASE OF SERVICING.
- MICROMETER ADJUSTMENTS FOR ACCURATE PEN ALIGNMENT.
- PEN MOTOR OVERLOAD PROTECTION.
- REMOTE CONTROL (OPTIONAL).

Write for complete specifications on Massa Recorders.

Other MASSA Products

SONAR TRANSDUCERS
ACCELEROMETERS — HYDROPHONES
MICROPHONES — AMPLIFIERS
COMPLETE LINE OF MULTI-CHANNEL AND PORTABLE RECORDING SYSTEMS

MASSA
A DIVISION OF
COHU
ELECTRONICS INC.

8 FOTTLER RD.
HINGHAM, MASSACHUSETTS

CIRCLE 73 ON READER-SERVICE CARD

COMPACT DIGITAL COMPUTER

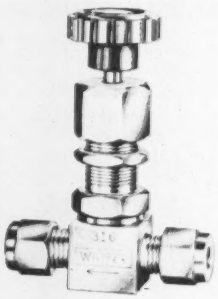
New Recomp II a general-purpose, all transistorized, Digital Computer with built-in floating point arithmetic and automatic decimal conversion performs additions at the

rate of 1,852/sec, fixed point multiplication in 10.8 msec, and floating point multiplication in 12.4 msec. The magnetic-disk memory contains 4,096 words, each of 40-bit length, including 16 words placed in high-speed loops. It can retain 8,000 instructions at a time, or stores more than 49,000 decimal digits of data. Shown in picture are the major components: electric typewriter for input and printed output; control console with basic computer control switches, visual display and control features; paper tape punch and photoelectric reader equipment; and the main computer package. Publication 508-T gives details.—*Autonetics, a div. of North American Aviation, Inc., Industrial Products, 3584 Wilshire Blvd., Los Angeles 5, Calif.*

CIRCLE 175 ON READER-SERVICE CARD

NEEDLE VALVES

New Regulating Needle and Fingertip Control Valves furnished in stainless steel, Monel and Hastelloy, in

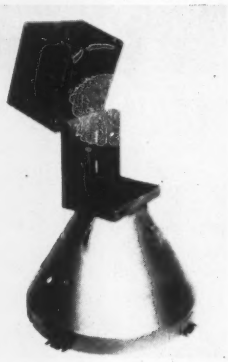


sizes from ⅛" to ½" are particularly recommended for applications involving the processing of viscous and volatile liquids, and for gases at high and low temperature, pressure vacuum and corrosion conditions.—*Whitey Research Tool Co., 1150—55th St., Oakland, Calif.*

CIRCLE 176 ON READER-SERVICE CARD

MAGNETIC SHIELD FOR 20" CR DISPLAY TUBE

New Netic Co-Netic Magnetic Shield incorporating a special shielded enclosure for electromechanically driven yoke assemblies is for 20" or larger CR display tubes. Stray magnetic fields radiated by associated



components are diverted by the shield allowing them to be mounted in close proximity to the tube without upsetting the display. No periodic annealing is required to maintain shielding effectiveness because the Netic Co-Netic Alloys are non-shock sensitive and non-retentive.—*Magnetic Shield Div., Perfection Mica Co.,* 1322 *No. Elston Ave., Chicago,* 22, *Ill.*

CIRCLE 177 ON READER-SERVICE CARD

MACHINE-DIVIDED SCALES

Made with latest SIP Swiss Automatic Dividing Machines

LINEAR

Accuracy to ±5 microns (0.0002")

CIRCULAR

Accuracy to ±5 seconds

Any scale pattern—Any line width—Any material

FINE MACHINE ENGRAVING

Scales, Dials, Drums, Rods, Panels

ACCURATELY ETCHED RETICLES

Made in any specified pattern and dimensions

PRECISION MACHINE-RULED MASTERS

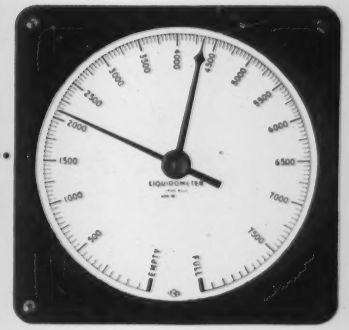
For printed circuits, i.e., commutators, switches, and general circuitry

L. C. RENICK CO.

308 So. Salsipuedes St., Santa Barbara, Calif.
formerly Cicero, Illinois

CIRCLE 74 ON READER-SERVICE CARD

don't guess Liquid Levels...



Specify a Liquidometer Gauge

Easy to read as a clock. A Liquidometer Gauge indicates the exact level at all times ... shows it at a glance. And gauge operation is completely automatic – as far as 250 feet from the tank – without need for auxiliary power of any kind.

A Liquidometer Tank Gauge measures virtually any liquid. It's simple to install – requires no maintenance. Many have provided over 30 years of efficient, dependable service. All are approved by Underwriters' Laboratories and Factory Mutual.

Whether your gauging needs require an automatic Liquidometer Gauge, a hydrostatic Levelometer or a tank-site-indicating Direct Reader, you'll get the best by specifying Liquidometer. For complete details write Dept. E.

Since 1920 ...of proven quality

THE LIQUIDOMETER CORP.

LONG ISLAND CITY 1, NEW YORK

CIRCLE 75 ON READER-SERVICE CARD

This is the New

TALLY

Bi-directional
Paper Tape Reader

It reads paper tape rapidly and economically

Tally Series 424 Paper Tape Readers furnish a new low cost approach to rapid search and accurate punched paper tape reading. Self contained, this unique bi-directional asynchronous reader is available in both rack and console styles.

It features...

A reading rate of 60 characters per second in either direction—instantly reversible. Triggered tape feed readout. Full accountability with form C switch providing positive hole/space identification. Reads 5, 6, 7, or 8 channels without modification. Low cost, only $595 for console unit. Can be slaved to any other 60 character device.

It's ready for delivery now

For full technical information including a 6 page folder and the name of your nearest Tally engineering representative, please write department 5512.

TALLY
REGISTER CORPORATION
5300 14th Avenue N.W., Seattle 7, Wash.

CIRCLE 76 ON READER-SERVICE CARD

NEW INSTRUMENTS

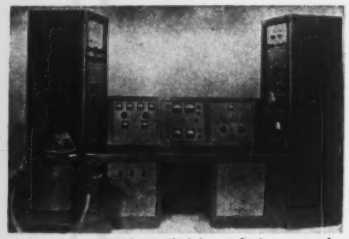
POWER SUPPLY HAS 0.005% REGULATION

New Zener-transistor-circuit power supplies feature standards accuracy of ±0.005% of *setting*. Many ranges are available. One has output of 0-15 volts at 200 ma with 95-115 v 60-cps input. Ripple is below 125 μv; output impedance is less than 0.01 ohm from 0 to 20 kc; recovery time is better than 25 μsec. Regulation accuracy of ±0.005% holds over full range of 95-135 v input and full range of load from 0 to 200 ma. Other voltage and current ranges also available at this accuracy.—*Cousins Magnetics Co., 523 E. 14th St., New York 9, N. Y.*

CIRCLE 178 ON READER-SERVICE CARD

VIBRATION TESTING SYSTEM

New Model CP-5 Randomatic is a completely packaged random noise and sine wave Vibration Testing System with a frequency range from 5 to 10,000 cps. Components include

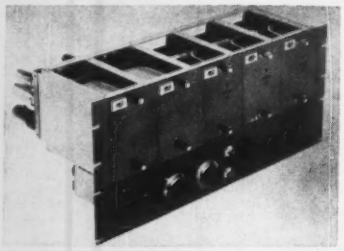


power generator, field and degaussing supply, cycling oscillator, servo system and stop-start controls, all housed in a single compact metal console and an external electro-dynamic shaker.—*Ling Electronics, Inc., Culver City, Calif.*

CIRCLE 179 ON READER-SERVICE CARD

D-C VOLTAGE COMPARATOR

New Model DLI-205 Comparator for rapid, accurate go/no-go indication of d-c voltage levels, particularly



valuable in automatic component testing, system check-out, or process monitoring, features a self contained Zener diode reference, true differential input giving 60-db common mode rejection, and 0.1% absolute accuracy. The two limit settings are established by 1000 division locking potentiometer dials.—*Electro Precision Corp., Arkadelphia, Ark.*

CIRCLE 180 ON READER-SERVICE CARD

A LOT OF CONTROL IN A SMALL SPACE

DAHL
"BANTAM"
VALVES

Dahl "Bantam" 2020, 2030 and 2031 series are highly compact, diaphragm-operated on-off valves. Each features the desired ruggedness and high quality of larger valves, and yet, allows appreciable savings in space. All have cast globe bodies for steam, liquid or gas applications.

"Bantam" valves have excellent flow characteristics, low hysteresis and fast response. Use of TEFLON® packings eliminates frequent packing adjustment and greatly reduces maintenance.

MAXIMUM Cv	40.0
LIFT	⅝"
SEAT AREA	up to 3.1 sq. in.
CONNECTIONS	¼" to 2" N.P.T.
PRESSURE RATING	150 psi for steam 300 psi for liquid & gas
OPERATORS	8, 15, 50 sq. in.

For more detailed information on "BANTAM" On-Off and Throttling Control Valves write for . . . . . Catalog B-1.

GEORGE W.
DAHL
COMPANY, INC.

86 TUPELO STREET, BRISTOL, RHODE ISLAND

CIRCLE 77 ON READER-SERVICE CARD

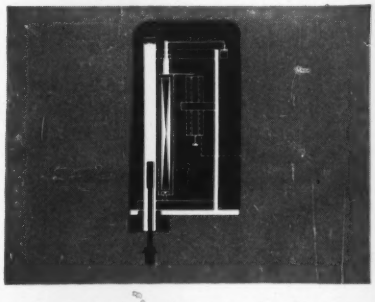
TRULY LINEAR ROTAMETER FLOW TRANSMITTER

Compatible With Any AC or DC Control Instrument

Brooks' new MPT-52 Electric Flow Transmitter* is remarkably adaptable. You can use it with any indicating, recording or control instrument . . . from a simple DC microammeter on up to the most sophisticated electronic unit. Just name the instrument, and Brooks will supply the proper transmitter package.

The MPT-52 is remarkable in other ways, too. It gives a linear signal based on actual flow rate—not float position. A unique flow-sensing cam in the transmitter does the trick: shaped according to the actual flow curve of the rotameter, it accurately transmits the meter's flow characteristics.

Designed to meet UL requirements for Class 1, Group D, Div. 1 hazardous locations, the MPT-52 is unaffected by vibration, extreme changes in ambient temperature, or dirty and corrosive atmospheres.



BULLETIN 170 gives full details. Write for a copy. *Pat. Pend.

BROOKS ROTAMETER COMPANY

1259 J STREET, LANSDALE, PA.

S.A. 1950

CIRCLE 78 ON READER-SERVICE CARD

POWER TEST SET

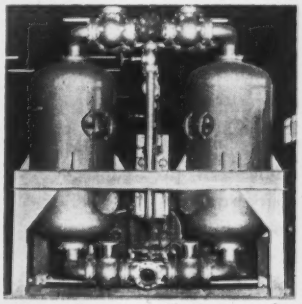
New Electrical Analyzer for a-c power, Model TS-1261/U, consists of a group of interconnected meters for measuring current (300 amp. max.),

power (0 to 1 kw), power factor, and voltage (600 v max.) All meter elements are of the electrodynamometer type and are temperature compensated. Accessory current and potential transformers extend ranges to 2500 v and 1000 amp. Frequency range is 25 to 400 cps.—*Niagara Electrical Instrument Co., 45 Allen St., Buffalo 2, N. Y.*

CIRCLE 181 ON READER-SERVICE CARD

DESICCANT DRYER

New Dessicant Dryer, Model 3500-HA, has a capacity of 3300 scfm @ 100 psig, or 7600 scfm @ 250 psig.



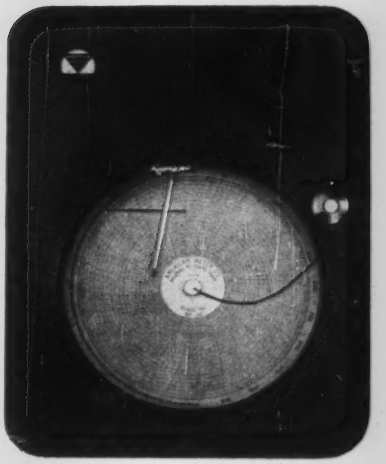
Chambers have a diameter of 40", while the overall height of the unit is 11'6".—*Trinity Equipment Corp., Cortland, N. Y.*

CIRCLE 182 ON READER-SERVICE CARD

LIQUID LEVEL GAGE

New power-operated Liquid Level Tank Gage, the Dynamatic, uses a servo motor to handle all movements within the gaging system. The complete system constitutes a force-balance system consisting of two elements, (1) a force-measuring mechanism composed of a torque tube, arm and servo motor switching contacts, and (2) a displacer composed of any material suitable to the environmental conditions. Accuracy is better than $\frac{1}{16}$", sensitivity is better than $\frac{1}{64}$" and the repeatability is better than $\frac{1}{32}$".—*The Vapor Recovery Systems Co., 2820 N. Alameda St., Compton, Calif.*

CIRCLE 183 ON READER-SERVICE CARD



AMERICAN®

PRESSURE and TEMPERATURE RECORDERS

American® single and two-pen *Pressure Recorders* for pressures from 30 inches vacuum to 10,000 psi.

- Pressure elements individually calibrated over full range.
- Variety of chart drives available.
- Helical elements of different ranges are interchangeable.
- Stainless steel pen arms with span and linearity adjustments.
- Aluminum dust and moisture-proof case.

American® *Temperature Recorders* for an accurate record of flowing temperatures.

- No ambient temperature errors.
- High sensitivity and torque—fast speed of response.
- Standard 0-150°F. range. Other ranges available by request.
- 24-hour mechanical or 110-v. 60-cy. electric chart drives.

Ask for Bulletins 400 and 408

AMERICAN®
METER COMPANY
INCORPORATED (ESTABLISHED 1836)

General Offices: Philadelphia 16, Pa.
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CIRCLE 79 ON READER-SERVICE CARD

C & S Force Calibrators

With guaranteed direct reading accuracies of 1/20 of 1%, these Cox and Stevens kits set new standards of precision and portability in force and weight measurement. They combine the high accuracy of laboratory equipment with the ruggedness required for field service.

C & S Force Calibrators are designed for on-the-spot, field calibration of testing machines, thrust stands, electronic, hydraulic or lever weighing systems, and can also be used for general purpose, single-point weighing operations. Containing a single load cell, the kits are light, compact and easy to use; available in capacities of 5,000 to 100,000 pounds.

Here are some of the features:

1. High guaranteed accuracy: 0.05% of applied load
2. Fast, direct reading: no conversions or corrections needed
3. 115 V AC operation (24 V DC optional)
4. Compact: All instrumentation, adapters, etc. in one carrying case
5. Portable: Watertight case weighs approximately 50 pounds
6. Easy to use: 50 foot cable plugs into cell
7. Rugged: Multi-column cell has an overload capacity of 225% of rated load

REVERE CORPORATION OF AMERICA

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A SUBSIDIARY OF NEPTUNE METER COMPANY

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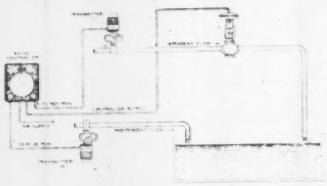
CIRCLE 80 ON READER-SERVICE CARD

RATIO CONTROLLER

New 60000-Series Ratio Controller is based on the 60000 Series instrument design and has two primary



elements: a control mechanism, and a ratio unit which is actuated directly by changes in the independent variable. Available in both indicating and recording models. Illustration shows flow ratio-control.—*Mason-Neilan, Div., of Worthington Corp., Nahatan St., Norwood, Mass.*

CIRCLE 184 ON READER-SERVICE CARD

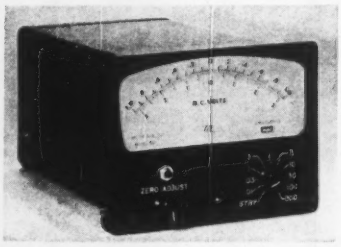
TANK GAGES

New, completely redesigned line of remote-indicating, manometer-type, Continuous-Purge Tank Gages for any size or shape vessel, open or closed, overhead or underground, requires only two air line connections for open tanks, three for closed or pressurized tanks. Multiple-tube instruments have manifolded air supplies so that only one supply connection is necessary.—*Meriam Instrument Co.*, 10834 *Madison Ave., Cleveland 2, Ohio.*

CIRCLE 185 ON READER-SERVICE CARD

ELECTRONIC MILLIVOLTMETER

New chopper-stabilized Electronic Millivoltmeter, Model 301, for d-c voltages from 0.0005 to 300, features two feedback loops for operational stability and to make it independent



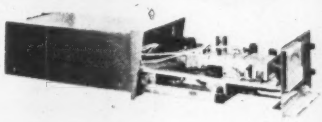
of voltage variations. An a-c loop is in the circuit of the a-c square wave amplifier. A d-c loop, including the chopper itself, is established by returning the metered demodulated signal via the chopper to the input of the instrument. Other models in the series are the zero-center Model 301-C used as a voltage-sensitive null indicator; Models 301-CMR and 301-C-CMR,

both equipped with double-locking contacts mounted on adjustable pointers; and Model 300-CRMR, with the new continuous-reading meter-relay. —*Metronix, Inc., Chesterland, Ohio.*

CIRCLE 186 ON READER-SERVICE CARD

INFRARED ANALYZER

New portable infrared Analyzer Model 300 LIRA, for industrial process streams and atmospheres, features unitized construction of amplifier, optical bench power supply, and control



panel to convert rapidly from one analytical problem to another. Typical ranges include: 0 to 0.2% CO or CO_2 in furnace atmosphere control; 1 to 50% relative humidity in process streams; 0 to 1% total hydrocarbons in combustion control; 0 to 100% lower explosive limit of natural gas; and 0 to 5% cyclohexane in chemical or petrochemical process streams.— *Mine Safety Appliances Co., 201 N. Braddock St., Pittsburgh 8, Pa.*

CIRCLE 137 ON READER-SERVICE CARD

MICRO-MODULE UHF TRANSISTOR

PHOTO SYSTEMS

HIGH RESOLUTION

"YALE" CAMERA

Custom-built precision camera systems for ultra-resolution of patterns . . . distortion free . . . on Kodak high-resolution plates, 1 x 3" or 2 x 10".

Diamond Ordnance Fuse Laboratory type as described in literature with *increased* range and convenience . . . micron range tolerances.

Write us with full details of your project. Delivery schedules now being processed.

Free 132 pg. Photo Equipment & Instrumentation Catalog.

BURKE & JAMES, INC

321 S. Wabash Chicago 4, Illinois

CIRCLE 81 ON READER-SERVICE CARD

WORLD STANDARD FOR SAFETY

2600

2740

in process safety-relief valves

From the Near East to our own Far West . . . the name Farris on safety-relief valves has been a standard synonym for safety since 1943. The patented design features on all Farris full-nozzle valves combine to offer the ideal concept of a trouble-free, 100% safe safety-relief valve for every application.

2745

2950

SERIES 2600

The most popular top-guided, self-aligning, safety-relief valve for process piping service. Maximum pressure, 150 to 2500 psig, RF/RJ. Plain or Lever types. Standard or BalanSeal bellows construction.

SERIES 2740

A cast-steel relief valve of simplified design for use where extreme blow down accuracy is not essential, but where durability, compactness are. Pressures to 3500 psig at 450°F; 2000 psig at 800°F. Sizes ½" to 2".

SERIES 2745

An extremely rugged, compact, high pressure bar stock nozzle valve. Internal parts stainless steel. Adjustable blow down; flat seat; self-aligning stem and disc. Pressure to 10,000 psig. Sizes ½", ¾", 1".

SERIES 2950

A cast iron safety-relief valve including most of the exclusive Farris features found in the Series 2600. Max. pressure, 250 psig at 450°F, 400 psig at 150°F. Plain cap, open lever or packed lever types.

Complete information is provided in Catalog FE-118, covering both selection and sizing of Farris process Safety-Relief Valves. Send for your copy today.

PROGRESS THROUGH HONEST PURPOSE Farris

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CIRCLE 82 ON READER-SERVICE CARD

Outstanding Accuracy

PALMER

Dial Thermometer

Check these functional features

- Direct-drive Bourdon Coil with a filled system for longer lasting accuracy.
- Stem can be placed at any desired angle and case can be rotated to most readable position.
- External calibration for zero setting.
- Unaffected by stem alignment.
- Accurate to one scale division.
- No sticking at any temperature.
- Non-corrosive case.

PALMER

THERMOMETERS, INC.

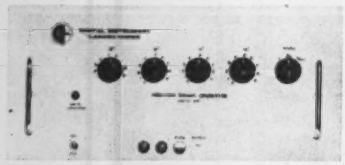
Mfrs. of Industrial Laboratory, Recording and Dial Thermometers

2515 Norwood Ave., Cincinnati 12, O.

CIRCLE 83 ON READER-SERVICE CARD

SIGNAL GENERATOR

New digital-controlled Signal Generator, Model 320, for f-m telemetry discriminator systems provides continuous automatic correction of output frequencies. Frequency range is

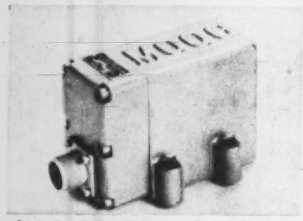


100 cps to 100 kc, with 0.02% accuracy at all frequencies. Additional applications are as a laboratory frequency standard and as an accurate frequency source for use in calibrating complex electronic systems.—*Digital Instrument Labs., a subs. of Telemetry Magnetics, Inc., 5115 Via Corona, Los Angeles, Calif.*

CIRCLE 188 ON READER-SERVICE CARD

INDUSTRIAL SERVOVALVES

New 71 Series high-performance Industrial Servovalves, available in production quantities in four sizes;



rated 1.0, 2.5, 5.0, and 10.0 gpm at 1000 psi valve drop and 15 ma input current; operate at system pressures ranging from 500 to 4500 psi. Product Bulletin 104 contains details.—*Moog Servocontrols, Inc., East Aurora, N. Y.*

CIRCLE 189 ON READER-SERVICE CARD

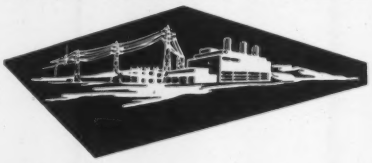
TWO-CHANNEL RECORDER

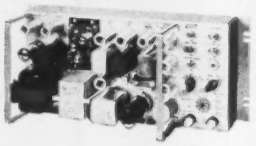
New Model G-22 Dual-Channel strip-chart Recorder is made portable and with panel-mount. Interchangeable plug-in input chassis on each

channel permit various recording characteristics to be used. Range is adjustable from 0-9 mv to 0-100 mv. Zero can be set anywhere across the chart. Two speeds are standard, four speeds optional.—*Varian Associates, Instrument Div., 611 Hansen Way, Palo Alto, Calif.*

CIRCLE 190 ON READER-SERVICE CARD

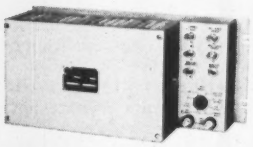
Telemeter ANY VARIABLE from Remote Points





MODEL 1025 Transmitter

MODEL 1090 Receiver



Accurate, Fast Acting, Frequency Type Telemeter for Transmission over Wire Lines, Microwave, and Power Line Carrier

Accurate HIGH-SPEED Continuous Telemeter for VOLTS AMPS WATTS VARS ETC.

•

Built-in Self-Calibrating Circuit

•

The Model 1025 Telemeter Transmitter converts DC mv from thermal converters, etc., to 10-30 cps which frequency modulates a built-in audio tone channel. AC 10 to 30 cps or relay outputs are also available. Receiver detects and demodulates transmitted signal, generating a DC mv for operation of recorders or indicating instruments. Up to 45 telemeters can be multiplexed.

Any communication link, including power line carrier, microwave or wire line may be used.

Over-all accuracy is 1% with a response speed of 1 second. Equipment features a built-in calibration circuit for 10% and 90% receiver check, and 10 cps and 30 cps transmitter check.

Any quantity which may be converted into a DC millivoltage or will operate a slidewire may be telemetered.

WE CAN HELP YOU

Our Applications Department is ready to assist you in your control, telemetering or communications problem. Phone DEerfield 4-3100.

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Radio Frequency LABORATORIES, INC.

Boonton, New Jersey, U. S. A.

CIRCLE 84 ON READER-SERVICE CARD

for your voice communications

STROMBERG-CARLSON TELEPHONE HANDSETS

MODELS FOR MANY INDUSTRIAL APPLICATIONS

No. 26: short, lightweight, sturdy. Comes with capsule-type receiver and transmitter.

No. 27: high-gain version of No. 26 handset.

No. 28: "push-to-talk" handset. Rocker bar switch; various spring combinations.

No. 29: high-gain version of No. 28 handset.

Typical applications: mobile radio • intercom systems • carrier and microwave • aircraft and railroad.

Modern handset cradle for mobile or panel use fits any Stromberg-Carlson handset.

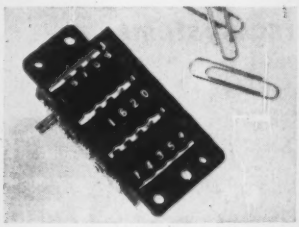
Send for Bulletins T-5005 and T-5013. Write to Telecommunication Industrial Sales, 113 Carlson Road, Rochester 3, New York.

STROMBERG-CARLSON
A DIVISION OF GENERAL DYNAMICS

CIRCLE 85 ON READER-SERVICE CARD

THREE-BANK COUNTER

New miniaturized three-bank Ratio Counter was developed for a military radio transmitter, permitting it to tune three bandwidths on one dial of the data readout type. In use, the second bank displays a total equal to twice the reading of the first bank.

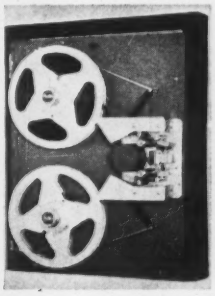


The third bank shows twice to total of the second bank, i.e., an example would be 0120, 0240, and 0480. Since these ratios are fixed and are brought about simply by proper arrangement of the numeral sequence on the wheels, the counter may be supplied in ratios to fit the customer's specific application. A shutter is incorporated so as to display only one bank at a time.—*Veeder-Root Inc., Hartford 2, Conn.*

CIRCLE 191 ON READER-SERVICE CARD

DIGITAL TRANSPORT

New Digital Transport, Model 3280, for low speed applications (from 10"/sec to 0.1"/sec), serves, for instance, as a coupling device to digital communication circuits or as a recorder of long term data occuring at low rates. Completely transistorized electronics, end of tape sensors, and adaptability to various reel configurations are some of the featured characteristics.—*Potter Instrument Co., Inc., Plainview, N. Y.*

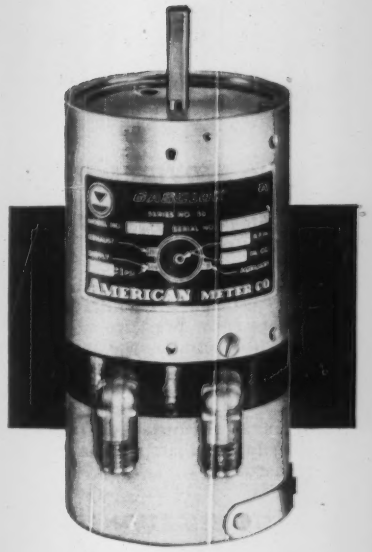


CIRCLE 192 ON READER-SERVICE CARD

THERMOCOUPLE WIRE

New Pycopack Thermocouple Wire of magnesium oxide-packed, metal-sheathed construction is available in seven sizes ranging from $\frac{1}{8}$" to $\frac{1}{40}$ (0.025)" sheath OD in all standard ISA calibrations (T, J, K, E, R and S). Standard sheath materials are Type 304 s.s., Inconel, and platinum. —*Pyrometer Co. of America, Inc., Penndel, Penna.*

CIRCLE 193 ON READER-SERVICE CARD



AMERICAN®

GASCLOK

POWER DRIVE

Completely self-contained gas or air-powered instrument driving and timing unit for long, trouble-free operation in remote locations. The GASCLOK delivers more than 20 times the torque of conventional spring-wound mechanisms. Continuous timing accuracy is unaffected by a ± 20% variation in supply pressure.

Inherently explosion proof and self-starting, the GASCLOK is ideal as original or replacement equipment for strip chart and conventional circular chart instruments. The timing mechanism is internally sealed to prevent corrosion, and all power unit parts exposed to gas are aluminum or stainless steel. Large area internal ports prevent clogging. Normal air or gas consumption 5 cfh . . . operating pressure 5 psi . . . rotation 2 rpm.

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INCORPORATED (ESTABLISHED 1836)

Executive Offices: Philadelphia 16, Pa.
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CIRCLE 86 ON READER-SERVICE CARD

DIGITAL TRANSDUCER

provides mechanical encoding for read-out and logging systems

The new Series 400 Digital Transducer utilizes a standard sensing element (flow, pressure, or temperature) to actuate the mechanical American Force Amplifier which precisely positions a shaft encoder. The need for electronic accessories is eliminated. Increased reliability and simpler maintenance are assured.

SPECIFICATIONS

Accuracy: 1% of span.
Repeatability: 0.5% of span.

WRITE FOR LITERATURE

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BOX 309 • GARLAND, TEXAS

CIRCLE 87 ON READER-SERVICE CARD

Here's one that doesn't have to be "Mothered"

You get continuous, trouble-free service from this rugged, reliable, direct-writing **RECORDING D. C. MICROAMMETER by Esterline Angus**

Built to "take it," this new D.C. Microammeter combines famous E/A excellence of design and ruggedness of construction with the extra-sensitivity of 0-50 microamperes at 200 ohms input resistance.

The simplicity of its direct-writing movement eliminates the complexity associated with servo or linkage driven writing systems.

It's a time-saver, too, with no unnecessary adjustments—such as continually setting zero. You put this D.C. Microammeter into operation merely by connecting the input leads.

Here's the recording instrument of a thousand and one uses. Send for Catalog Section No. 41 and see how it can help you.

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No. 1 in fine Graphic Instruments for more than 50 years.

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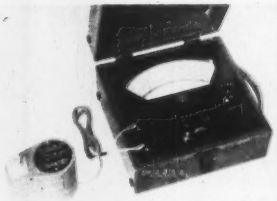
CIRCLE 88 ON READER-SERVICE CARD

CHECKING VOLTMETER

New thermocouple-type Laboratory Standard Voltmeter for checking all types of VTVM's at r-f voltages features high accuracy (1% or better

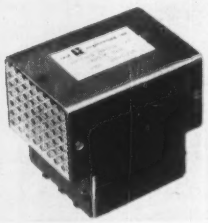


from dc to 100 Mcps), can be calibrated against accurate d-c standards and used as a transfer standard, and contains no amplifiers of any type. Five different types are available from 0-1 to 0-100 (at reduced frequency response).—*Rawson Electrical Co., 112 Potter St., Cambridge, Mass.*

CIRCLE 194 ON READER-SERVICE CARD

MAGNETIC MEMORY STACKS

New Series 3000 Apertured Ferrite Plate Memory Stacks, a line of miniature, magnetic storage plug-in modules, is for high speed random-



access memories and serial buffers. Available in standard sizes from 256 to 4096 words and 4 to 16 bits per word, they operate in a conventional coincident-current selection scheme, and replace assembled core arrays on a 1:1 basis. Switching time is 1.75 usec and output is 45 mv.—*Rese Engineering, Inc., 731 Arch St., Phila. 6, Pa.*

CIRCLE 195 ON READER-SERVICE CARD

RESISTANCE TEMP PROBE

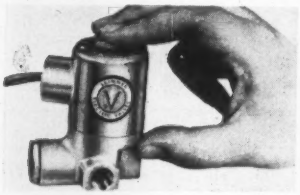
New Resistance Temperature Probes with integral pipe threads are available in three types: two types with minimum protection for the tem-

perature-sensitive winding (in order to provide a time constant of about 100 usec in liquids), and another type with a stainless-steel protective sheath having a time constant of two sec.—*Ruge Associates, Inc., Hudson, N. H.*

CIRCLE 196 ON READER-SERVICE CARD

H-P SOLENOID VALVES

New high-pressure Solenoid Valves in two-way, normally-closed construction and in a wide range of voltages and frequencies are made with orifice size of ¼" dia and ¼" NPTF ports. Operating pressure differentials are 5



to 1250 psi on a-c voltage and 5 to 1000 psi on d-c voltage. Bodies are forged naval brass, internal parts are s.s.—*Skinner Electric Valve Div., 105 Edgewood Ave., New Britian, Conn.*

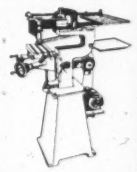
CIRCLE 197 ON READER-SERVICE CARD

TEST STAND

New test stand, Model PMB-100-C, is for use with a signal generator, amplifier, precision potentiometer, voltmeter and an oscilloscope, to measure and test linearity, phase, input and output volts, and operations at various frequencies.—*Schaevitz Engineering, Pennsauken, N. J.*

CIRCLE 198 ON READER-SERVICE CARD

YEAR END SUPPLIES NOW!

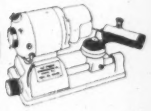


Check Model 2D-4 for engraving panels to 30" wide. Range: 1:1 to infinity.

JIM COLEAN
M.Q.BOLTEN
R. B. Louis
JOHN TRAVERS
A.B.KUYSER

Check Copy Type—More than 50 distinct copy styles. Sizes from ¼" to 6" high. Sunk reading right or reversed.

Check Cutter Grinder for sharpening your engraving cutters.



Check your cutter Supplies. High Speed Steel, Tungsten Carbide, Diamond Cutters.

A Full Line of Panto Engraving and Marking Machines

- Rotary Tables
- Copy Type Holders
- Work Holding Fixtures
- Endless Belts

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Write for complete details and prices. For immediate attention write directly to manufacturer below. Ask for nearest representative.

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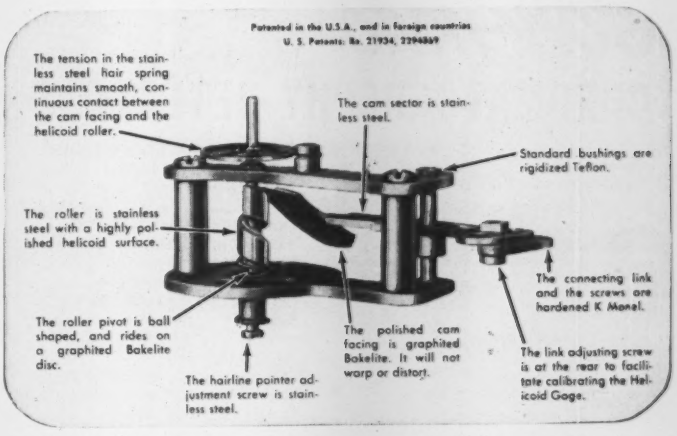
ACCO Helicoid Gage U.S.A.


Patented in the U.S.A., and in foreign countries
U. S. Patents: Re. 21934, 2294869
The tension in the stainless steel hair spring maintains smooth, continuous contact between the cam facing and the helicoid roller.
The cam sector is stainless steel.
Standard bushings are rigidized Teflon.
The roller is stainless steel with a highly polished helicoid surface.
The connecting link and the screws are hardened K Monel.
The roller pivot is ball shaped, and rides on a graphited Bakelite disc.
The polished cam facing is graphited Bakelite. It will not warp or distort.
The link adjusting screw is at the rear to facilitate calibrating the Helicoid Gage.
The hairline pointer adjustment screw is stainless steel.

Exclusive Helicoid movement provides... *Sustained Accuracy... on the toughest jobs*

• Helicoid Gages have no gears, no teeth, reducing wear to an absolute minimum. No danger of fouling, either—rolling action of cam facing keeps contact surface clean. Helicoid Gages have been tested through 75,000,000 cycles, with virtually no wear or loss of accuracy, while conventional geared gages became useless after 500,000 cycles.

Helicoid Gages give *sustained* accuracy even when subjected to violent pressure pulsations or mechanical vibrations. Pointer can be set externally, without removing glass, and cannot be jarred out of position. Dial faces are easy to read, won't corrode or chip. A full range of Helicoid Gages is available for any application. Next time, specify Helicoid—the gage that *stays* accurate.

Bourdon Tubes won't Stretch, Leak, or Crack

Helicoid Bourdon tubes are made from seamless tubing, and are designed for maximum torque and minimum stress. At the factory, each tube is individually tested, overpressured, and stress relieved. Four materials—alloy steel, K Monel, stainless steel, and phosphor bronze—are available to meet applications ranging from tap water to almost any acid.

NEW! Solid-Front Safety Case Gives Added Protection

The new Helicoid solid-front case diverts the force of a burst in a backward direction, away from the operator. The force escapes by deforming, though not detaching, the back cover plate. Helicoid Gages are also available in phenol, acaloy flanged, acaloy flangeless, polished flangeless, round flush, polished flush ring, and square flush cases.

WRITE for details

Ask for Catalog DH-65

HELICOID GAGES

ACCO

Helicoid Gage Division • American Chain & Cable Company, Inc.
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CIRCLE 90 ON READER-SERVICE CARD

Plumber's Nightmare
or Chemist's Dream?

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CHROMATOGRAPHY DETECTORS

Call or write for bulletins on
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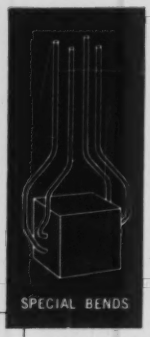
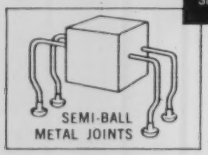
Hot-wire filaments in matched pairs.
Temperature Regulated Cells, ON STREAM and chromatography.
Pancake DC Power Supplies.
Portable GAS MASTERS.
Gas Blenders for forming gas.
Helium Purity Analyzer Recorders.





— **HAVE IMPROVED PERFORMANCE** because of lower pneumatic noise and easier installation from GOW-MAC (special sketch) SSK T/C cell assemblies with special gas flow connections for individual or O.E.M. designs.

— **LOWER LIMITS OF DETECTABILITY** from these specifications combined with new GOW-MAC solid state, special Pancake DC Power Supply with microdial zero adjust.

— **LOW-COST RELIABLE** GOW-MAC hot wire T/C units are products of continuous research.

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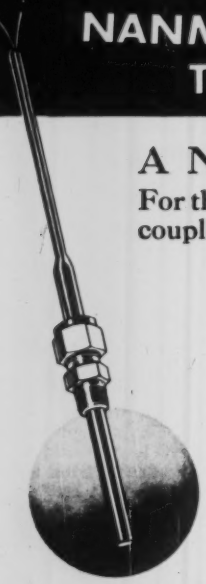
Telephone FRontier 7-3450

CIRCLE 91 ON READER-SERVICE CARD

Introducing a NEW, FAST-RESPONDING
NANMAC "PENCIL PROBE" THERMOCOUPLE



A NEW DESIGN . . .

For the first time - a pencil probe thermocouple with the following features:

✓ *Response time - less than 10 microseconds to transient flow.*

✓ *A continuous service temperature of over 2000° F.*

✓ *A sensing tip with unlimited life.*

Sensing tip constructed with flat ribbon thermocouple wires of .001 inch thickness and mica insulation of .0002 inch thickness. Thermocouple can be used as a surface, in-wall, or immersion thermocouple. Adjustable gland nut assures pressure seal to 3,000 PSI. All stainless steel construction. Available in all standard thermocouple combinations.

For additional details and models write for Technical Bulletin 250

NANMAC CORPORATION
P.O. BOX 8 INDIAN HEAD, MARYLAND

NANMAC THERMOCOUPLES

CIRCLE 92 ON READER-SERVICE CARD

NEW INSTRUMENTS

HIGH-VACUUM GAGE

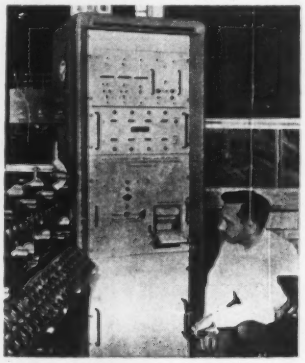
New combination Discharge gage and two-station Thermocouple gage control, DG2-2T, measuring pressures between 1,000 microns of Mercury and 5 x 10^{-6} mm Hg, combines two separate gages in one compact cabinet—a thermocouple gage and a Philips-type cold cathode discharge

gage. The thermocouple unit measures pressure response between 1,000 microns and 1 micron from either of two thermocouple gage tubes. Philips-type cold cathode unit is sensitive to pressures between 10 microns and 5 x 10^{-6} mm Hg.—*Veeco Vacuum Corp., 86 Denton Ave., New Hyde Park, L. I., N. Y.*

CIRCLE 199 ON READER-SERVICE CARD

HOT BOX DETECTIVE SYSTEM

New refined Servosafe Hot Box Detective System for spotting overheated freight car journals features a linear transistorized a-m voice-frequency carrier system coupled with an automatic alarm system. The

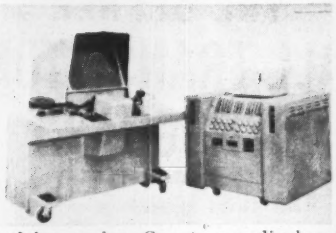


carrier, which operates on any of nine frequencies between 2125 and 3525 cps, greatly extends distances between scanners and office recording equipment. Equipment is so designed that locomotive and most passenger car journals are automatically excluded from the alarm system. This minimizes false alarms.—*Servo Corp., of America, Railroad Products Div., 4 Aerial Way, Syosset, L. I., N. Y.*

CIRCLE 200 ON READER-SERVICE CARD

FILM READING SYSTEM

New Dilog 510 Film Reader with high-speed electronic digitizing unit, measures distances along two axes on 16-mm to 70-mm sprocketted film and displays a magnified image. Digitizer is an accumulator which counts and stores measurement pulses gener-



ated by reader. Counts are displayed visually, or may be read out on electric typewriter, punched card, perforated tape or x-y plotter. Resolution is up to 60 lines/min.—*Data Instruments, a div. of Telescomputing Corp., 12838 Saticoy St., North Hollywood, Calif.*

CIRCLE 201 ON READER-SERVICE CARD

MOTOR TACH GENERATOR

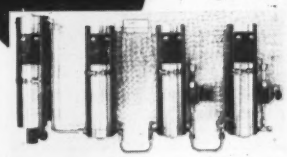
New Size 10 Motor Tach Generator is ⅓ shorter and ⅓ lighter than other Size 10 units, measures only 1.281" long and weighs only 2.5 oz.

Motor section has 26-v fixed phase and 35-v center tap control phase, 0.30 in-oz stall torque and 6500 rpm no-load speed. The generator section has 10-v input and 0.16-v per thousand output.—*John Oster Mfg., Co., Avionic Div., 1 Main St., Racine, Wis.*

CIRCLE 202 ON READER-SERVICE CARD

NEED DEHYDRATION OF GASES?

Investigate Robbins Aviation Dehydration Systems!



- *Remove water or oil vapor*
- *Working pressures up to 12,000 psi.*
- *Dew points -100°F • Oil vapor .3 ppm*

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METERING and OXYGEN VALVES
for both liquids and gases

NEED RELIABLE VALVES?

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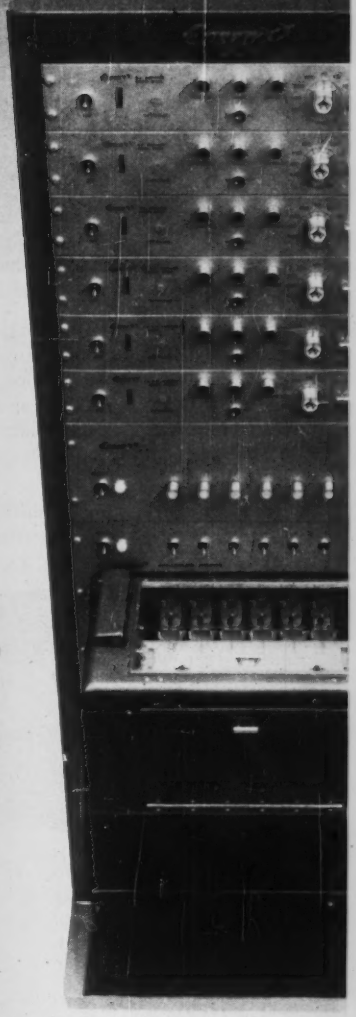


EPSCO WORCESTER RECORDERS LEAD THE FIELD

In production testing, research and development engineering for all industry where Versatility, Performance and Economy are essential.

Take a look at these important Angles.

VERSATILITY

Interchangeable amplifiers will accommodate a wide range of transducers. Whatever the level or character of the signal, there is an EPSCO preamplifier to handle it.

PERFORMANCE

Sensitivity — from 10uv per mm and Strain measurement as low as 1 micro-inch per inch per mm.
Frequency Response — from D.C. to 200 cps produced through Plug-in compensators which provide extended frequency response or sharp cut-off.
Chart Speed — from .05mm to 500mm per sec.

ECONOMY

- Low initial cost.
  Model 8205-6 (illustrated) 6 channel ink writing system complete $4,365.00
- Low operating cost.
  Compared to other writing systems, EPSCO's operating costs average up to 5 times less.

NO ADDITIONAL EQUIPMENT OR ACCESSORIES ARE NEEDED TO MAKE THIS DYNAMIC RECORDING SYSTEM COMPLETE.

30 Day delivery on all EPSCO WORCESTER Recording Systems.

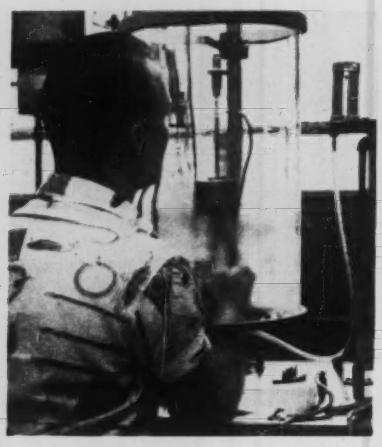
INSTRUMENTATION FOR INDUSTRY AND MEDICINE

Epsco WORCESTER
A DIVISION OF Epsco INCORPORATED

207 MAIN STREET WORCESTER 8, MASS. PLeasant 7-8394

CIRCLE 94 ON READER-SERVICE CARD

Varian protects hydrogen brazing operations with J-W gas detector



Construction of Varian Associates backward wave oscillator tube involves brazing two copper tubes with silver eutectic. In the operation shown an oxygen flame in a hydrogen atmosphere flows the eutectic.

Varian protects against a build-up of an explosive gas mixture in the shop with a J-W warning system. The indicating unit (model RV, shown at right) is situated in a central place and monitors nine work stations automatically at four minute intervals.

Varian's explosive gas detector system was designed to custom requirements. If you have an explosive gas hazard in your operations, contact Johnson-Williams for information on standard models and J-W engineering service on gas warning systems.

J-W Johnson-Williams, Inc.
Palo Alto 14, California

Leadership in explosion prevention since 1927

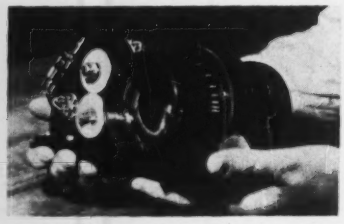
Canadian customers please write:
Safety Supply Co., Toronto, Ont.
Fleck Bros. Ltd., Vancouver, B. C.

CIRCLE 95 ON READER-SERVICE CARD

NEW INSTRUMENTS

HIGH-SPEED LENS

New 5½" high-resolution 1:1 Transfer Lens for Cathode-Ray Tubes, with relative aperture ranging from f/2 (at infinity) to f/22,

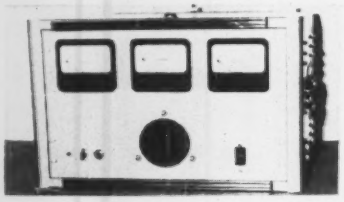


covers a 4½" diagonal format. Object-to-image distance is 17.6". Optional equipment available includes a reflecting unit to permit bending of the light path, and a motorized control for remote adjustment of the lens iris.—*Electro-Optical Div., Perkin-Elmer Corp., Norwalk, Conn.*

CIRCLE 203 ON READER-SERVICE CARD

HIGH-V TEST SETS

New KS series of small high-capacity test sets features both a-c and d-c output with separate KV meters for d-c output and a-c output, and a

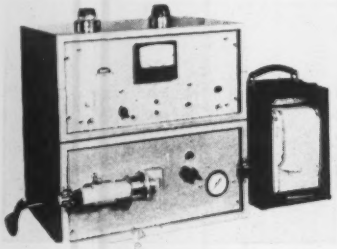


common a-c/d-c current meter. Other features include simple control circuitry with main switch, and continuously adjustable output from zero. Units are available from 0-2 kv at 50 ma (Model KS2-50) to 0-50 kv at 40 ma (Model KS50-40), with a maximum of 2 kva capacity.—*Peschel Electronics, Inc., RFD#1, Patterson, N. Y.*

CIRCLE 204 ON READER-SERVICE CARD

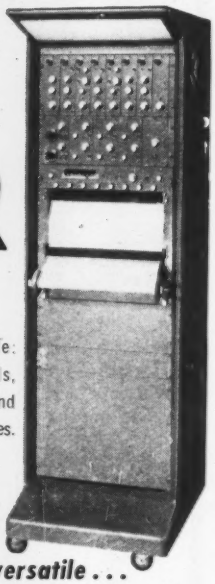
RADIOACTIVITY MONITOR

New portable Air and Area Monitor, Windjammer Model WJ-1, detects alpha-beta-gamma, or beta-gamma, or alpha rays only. It consists of two



THE OFFNER ALL TRANSISTOR DYNOGRAPH

TYPE R



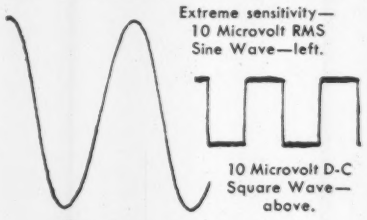
Models available: 1 to 19 channels, console, rack, and portable assemblies.

the most versatile . . . most sensitive direct-writing recorder available

Whatever your application for direct-writing oscillograph recording . . . investigate the ability of the Offner Type R Dynograph to do the job *better* and more *simply*. Its features of superiority are *unmatched!*

- ✓ High Sensitivity: 1 microvolt d-c per mm
- ✓ High Frequency Response: 0-150 cps— ±10%
- ✓ Large Linear Deflection: over 6 cm—½% linearity
- ✓ Wide Ambient Range: —20° C to +50° C
- ✓ Versatile: d-c, a-c, carrier, all with one set of amplifiers
- ✓ Convenient: Plug-in input couplers for all bridge balancing
- ✓ Stable: Drift—1 microvolt per hour at maximum sensitivity
- ✓ Recording Media readily interchangeable: Heat, Electric, Ink; Rectilinear, Curvilinear
- ✓ Compact: Eight channels in only 35" of rack space.

Write for full specs and complete details



OFFNER ELECTRONICS
3910 River Road, Schiller Park, Ill.
(Suburb of Chicago)

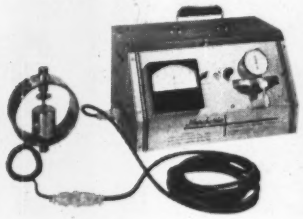
CIRCLE 96 ON READER-SERVICE CARD

integrated units: a count ratemeter, and air collector and filter employing magnetic shielding.—*Nuclear Measurements Corp., 2460 N. Arlington Ave., Indianapolis 18, Ind.*

CIRCLE 205 ON READER-SERVICE CARD

BALANCING INSTRUMENT

Newly redesigned Calibrating and Weighing System Balancing Instrument incorporates an extremely sensitive miniature cam, spring-loaded for positive adjustment, which replaces

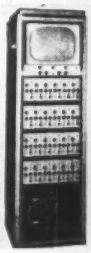


a potentiometer as the zero adjustment device; a vacuum tube; and Morehouse Proving Ring. The new zero adjustment eliminates undesirable phase relationship effects which are possible by using the potentiometer in a phase-sensitive instrument. —*Morehouse Machine Co., 1742 Sixth Ave., York, Penna.*

CIRCLE 206 ON READER-SERVICE CARD

MULTICHANNEL OSCILLOSCOPE

New Model RM-24, using a 17" long persistent cathode ray tube (17LP-7A) to display up to 24 channels of information simultaneously, features individual plug-in channel amplifiers, calibrated time base, high resolution, high sensitivity, and response from dc to 3500 cps.—*Rycom Instruments, a Division of Railway Communications, Inc., 9351 East 59th St., Rayton, Mo.*



CIRCLE 207 ON READER-SERVICE CARD

RED-READING THERMOMETER

New red-reading mercury industrial thermometer is made in six standard forms: straight—for top positioning on equipment; 90° back angle—for front mountings; 90° left side—for side mountings; reverse oblique and regular oblique— for slanting, perpendicular or below level mountings. All forms are supplied with either 7" or 9" scale cases.—*Tagliabue Mfg. Co., 87 Sewell St., Hempstead, N. Y.*

CIRCLE 208 ON READER-SERVICE CARD

HEISE GAUGES

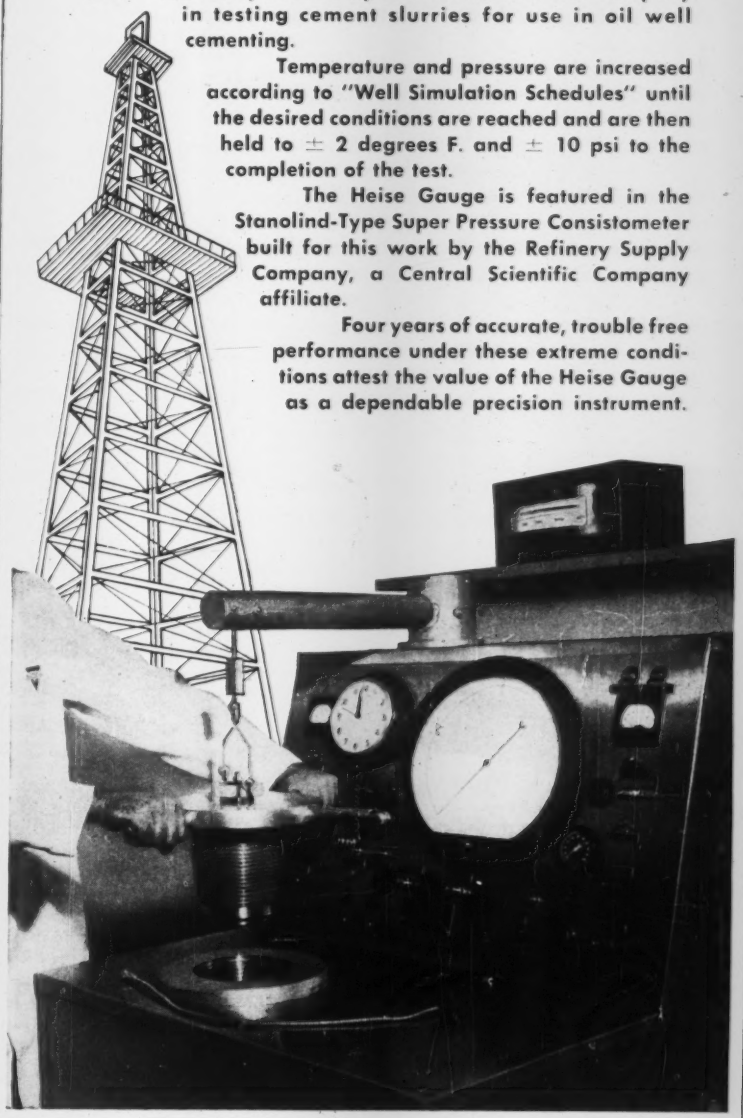
Indoor Oil Well

Pressures up to 20,000 psi at temperatures to 350 degrees F., encountered deep in the earth, are reproduced under laboratory control by the Continental Oil Company in testing cement slurries for use in oil well cementing.

Temperature and pressure are increased according to "Well Simulation Schedules" until the desired conditions are reached and are then held to ± 2 degrees F. and ± 10 psi to the completion of the test.

The Heise Gauge is featured in the Stanolind-Type Super Pressure Consistometer built for this work by the Refinery Supply Company, a Central Scientific Company affiliate.

Four years of accurate, trouble free performance under these extreme conditions attest the value of the Heise Gauge as a dependable precision instrument.



Pressure Ranges 15 to 20,000 P.S.I. Dial Sizes 8½"-12"-16"

Prices from $166.75 DELIVERY WITHIN 30 DAYS

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BROOK ROAD, NEWTOWN, CONNECTICUT, U.S.A.

CIRCLE 97 ON READER-SERVICE CARD

SAMPLE...PROTO-TYPE INSTRUMENTS

Available from this department within one week ARO, or sooner, if necessary, for small quantities.

The men in this department are highly skilled instrument technicians using the best standards and equipment available.

Phone or wire Sun Electric Corporation, Instrument Division, Collect for your immediate requirements of either standard or military types of panel meters.

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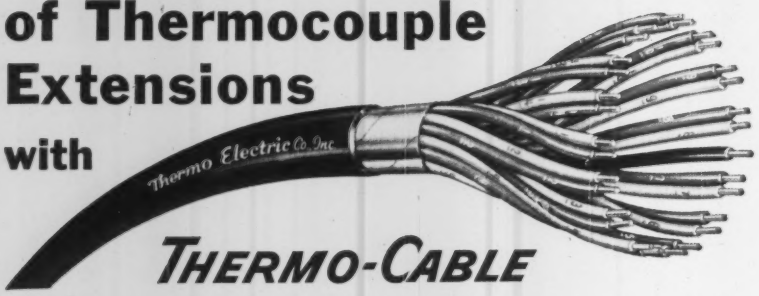
INSTRUMENT DIVISION

CIRCLE 98 ON READER-SERVICE CARD

Reduce Installation Costs of Thermocouple Extensions with THERMO-CABLE



You can now install 6 to 56 pairs of thermocouple leads at one time with "Thermo-Cable," T-E's new multi-conductor extension cable. Installed in conduit, "Thermo-Cable" reduces costs by eliminating the need to pull individual conductors—and permits the use of smaller conduit for the same number of leads. "Thermo-Cable" can also be installed without conduit, in open troughs or in raceways.

"Thermo-Cable's" smooth, polyvinyl chloride outer jacket resists moisture, heat, abrasion and chemical action—and slips easily through conduit. ISA color coded, individual conductors are also insulated in hi-temp (221°F.) polyvinyl chloride—and the conductor bundle is wrapped in aluminum-backed Mylar tape for electrostatic shielding. Pairs are numbered alike and lie next to each other. "Thermo-Cable" is available in 6, 14, 18, 25, 39 or 56 pairs and comes in all standard thermocouple materials.

Write For Wire Section 33-F

Thermo Electric CO., INC.

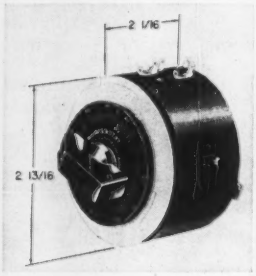
SADDLE BROOK, NEW JERSEY

In Canada: THERMO ELECTRIC (Canada) LTD., Brampton, Ont.

CIRCLE 99 ON READER-SERVICE CARD

SMALL VARIABLE TRANSFORMER

New 10B-Series of Powerstat Variable Transformers feature a 40% increase in rating with no increase in price or size. Operate from a 120-v, 60-cycle, 1-phase input with an output of either 0-132 or 0-120 v, 1.75 amp.

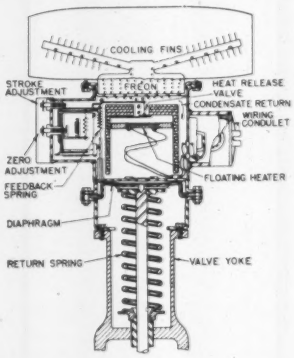


Input can be 50/60 cycles when connected for an output of 0-120 v. With a constant-impedance load and connected for a 0-120 v output, the allowable current at maximum output voltage is 2.5 amp. 8-page Powerstat Bulletin P159 gives details.— *Superior Electric Co., Dept. 10B, Bristol, Conn.*

CIRCLE 209 ON READER-SERVICE CARD

THERMO DRIVE ACTUATOR

New, improved model of the vapor-powered Thermo-Drive Actuator for electronic control systems is characterized by several design refinements



which permit stroke and zero adjustments, and provide full operating thrust with lower internal pressures through a more efficient vapor producing liquid which has a boiling temperature at a pressure less than 40 psig.— *Swartwout Co., Inc.*, 18511 *Euclid Ave., Cleveland* 12, *Ohio.*

CIRCLE 210 ON READER-SERVICE CARD

AUTOMATIC WATER ANALYSIS

New AutoAnalyzer continuously samples make-up water, detects tiny traces of silica, and indicates silica concentration with high accuracy. The

characteristic blue color indicating silica concentration is developed in the stream. Color intensity is measured in a flow-type colorimeter and its value is plotted continuously on the strip chart of a Bristol recorder. Heart of the unit is a precision proportioning pump which can handle as many as eight reagents simultaneously.—*Technicon Controls, Inc., Chauncey, N. Y.*

CIRCLE 211 ON READER-SERVICE CARD

PRE-MIXED CHEMICALS KIT

New Pre-mixed Liquid Chemicals Kits for use with CEC's Type 23-109A Oscillogram Processor develop and stabilize oscillograms without the need to mix powders. Kit contains four envelopes of liquids, formulated and packed by Atkinson Lab. Addition of warm water makes the solutions ready for use.—*Electro Mechanical Instrument Div., Consolidated Electrodynamics Corp., 360 Sierra Madre Villa, Pasadena, Calif.*

CIRCLE 212 ON READER-SERVICE CARD

Direct Reading

FREQUENCY MODULATION

VOLTAGE MODULATION

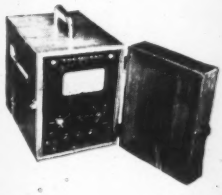
on 400 CPS Systems

MODULATION TEST SET T97

Reads percent frequency and voltage modulation on separate meters. Measures and records transients of voltage and frequency. For field and laboratory use on aircraft power systems, ground power systems.

FREQUENCY MODULATION METER T180

Reads frequency modulation on meter calibrated in percent. Records frequency transients with an output signal. For checking constant speed drives and frequency regulators in aircraft electrical systems.



For detailed specifications, write

Dept. C-12

AVTRON MFG., INC.

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CIRCLE 100 ON READER-SERVICE CARD

Something Special

IN A **STANDARD STANDARD**

For those jobs, only a manometer can do . . .

When you're faced with precision calibration, production checks of other accurate instruments, or any kind of laboratory pressure work . . . in fact, any time you need better than 0.1% accuracy that's the time to add a W&T precision mercurial manometer.

Rapid readout with the magnified magnetic vernier makes exact pressure readings easy. All 'round leveling, temperature compensation and gravity correction are included, of course.

range: 0 to 31.50 inches Hg., or any other desired pressure unit of equivalent range.

accuracy: 1/5000 over full scale.

For full information on all models of W & T precision mercurial manometers, write Dept. A-121.48

WALLACE & TIERNAN INCORPORATED

25 MAIN STREET, BELLEVILLE 9, NEW JERSEY

IN CANADA: WALLACE & TIERNAN LTD., WARDEN AVE., TORONTO 13, ONT.

is your feeding problem peculiar to your operation?

Wallace and Tiernan's volumetric feeders are so flexible that each job is practically custom built. W&T's experience is broad enough to meet any challenge.

Try us - for information write Dept. MV-1.48

WALLACE & TIERNAN INCORPORATED

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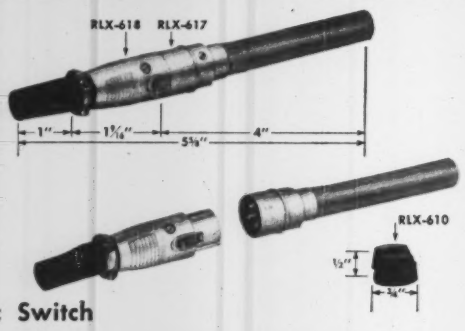
MANOMETERS: CIRCLE 101 ON READER-SERVICE CARD

VOLUMETRIC FEEDERS: CIRCLE 102 ON READER-SERVICE CARD

POST DECITRON ELECTRONIC PRODUCTS



NEW!

MH-2-P Magnetic Switch

A new and improved sensing device . . . neatly contained in an epoxy resin shell. The MH-2-P is ideal for industrial applications and is easier to mount in areas of limited access. A quick disconnect Cannon connector eliminates elbow type construction.

The new epoxy resin housing results in less magnetic flux and increased sensitivity. As a consequence, smaller magnets can be used and manufacturer reports a minimum magnetic field transient time of only 8 milliseconds is needed to activate the switch. Operating life is in excess of one billion operations.

Write For Bulletin MH-2-P

Decitron

ELECTRONIC PRODUCTS DIVISION

Post Machinery Co. | 175 Eliot St., Beverly, Mass.

CIRCLE 103 ON READER-SERVICE CARD

JOHN WORLEY JEWEL COMPANY 1900

JEWEL BEARINGS and TUNGSTEN CARBIDE BEARINGS and ORIFICES in Sizes under 1/4" O. D.

We specialize in instrument bearing design problems and production of pilot lots in our own plant in the U.S.A. We also offer top quality Swiss imports at low production prices.

JOHN WORLEY JEWEL CO.

No. Falmouth, Massachusetts

CIRCLE 104 ON READER-SERVICE CARD

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Visualisation

Instrumentation

Schlieren Systems

Shadowgraphs

Interferometers

Wind Tunnel Optics

Mountings & Piers

Packaged Systems

Catalog upon request

John Unertl Optical Co.

3551-3555 East Street

Pittsburgh 14, Penna.

CIRCLE 105 ON READER-SERVICE CARD

NEW INSTRUMENTS

TAPE PREPARATION CONSOLE

New Tape Preparation and Editing Console which accepts standard tape widths of 0.687", 0.875", and 1.000" consists of a numerical keyboard, a control and comparison section with

6-digit decimal readout, two tape readers, and one tape perforator. Key features are tape-to-tape duplication and verification at 60 characters/sec; keyboard visual display and shift register to eliminate copying errors; automatic error alarm; and tape corrections without over-punching or splicing.—*Tally Register Corp.*, 5300—14*th Ave., N.W., Seattle 7, Wash.*

CIRCLE 213 ON READER-SERVICE CARD

DIGITAL MILLIVOLTMETER

New portable Ratio Digital Millivoltmeter includes several functions: instrument power, standard cell, ratiometer, bridge balance, millivoltme-

ter, voltage level, and endpoint offset, reading 10 mv and 100 mv full scale to 0.1% accuracy.—*Technical Industries Corp.*, 389 *North Fair Oaks, Pasadena, Calif.*

CIRCLE 214 ON READER-SERVICE CARD

READ-THROUGH LAMP

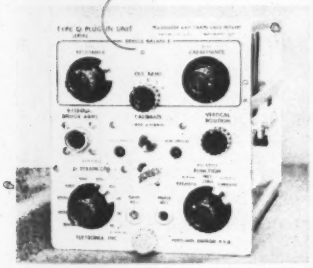
New subminiature incandescent Read-through Lamp #4, designed for computer use as a light source in a

photoelectric readout application, is rated 2.5 v, 400 ma, and available with either a brass midget snap-in base for simple front-replacement, or as a wire lamp suitable for soldering or welding directly into a computer circuit.—*Tung-Sol Electric Inc., One Summer Ave., Newark 4, N. J.*

CIRCLE 215 ON READER-SERVICE CARD

STRAIN GAGE PREAMPLIFIER

New Type Q Preamplifier achieves the equivalent of d-c amplification by amplitude-modulating a 25-kc carrier voltage, supplied by the plug-in unit,



to equip Tektronix Oscilloscopes for use with strain gages and other transducers. Frequency response is dc to 6 kc, risetime is approximately 60 usec, strain sensitivity 10 microstrain (microinches per inch) per major graticule division to 10,000 microstrain per division, continuously variable.—*Tektronix, Inc., P.O. Box 831, Portland 7, Ore.*

CIRCLE 216 ON READER-SERVICE CARD

HARDNESS TESTING

SCLEROSCOPE
FOR TESTING THE HARDNESS OF METALS. PIONEER AMERICAN HARDNESS STANDARD. OVER 40,000 IN USE. (ASTM A427)

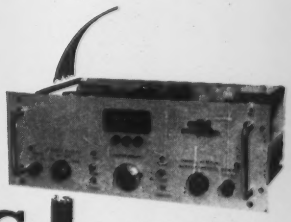
DUROMETER
FOR TESTING THE HARDNESS OF RUBBER & RUBBER-LIKE MATERIALS (ASTM D676) (ASTM D1484)

SHORE INSTRUMENT & MFG. CO., INC.
90-35 VAN WYCK EXP.
JAMAICA 35, N. Y.

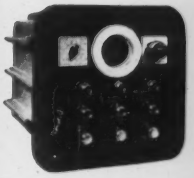
CIRCLE 106 ON READER-SERVICE CARD

COX *Electronic*

FLOW MEASURING SYSTEM

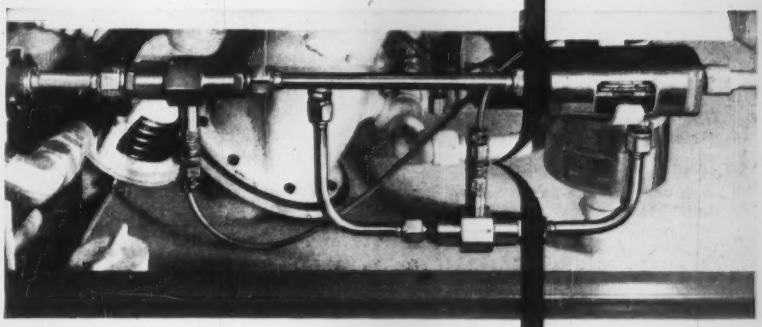


RACK MOUNTED INDICATOR



EXPLOSION-PROOF INDICATOR

COX Instruments brings you the most advanced development in flow measuring equipment: *A calibrated, integrated flow measuring system with a guaranteed system accuracy of ± ½% and flow ranges of 1:1000.*



Developed for the missile age, the COX *Flow Measuring System* consists entirely of COX-built components. It comprises a turbine flow transducer; a choice of continuous reading digital indicators, counter, or dial indicator; and a manifold assembly with a unique automatic by-pass valve. All are calibrated for *system accuracy* of ½%.

TRANSISTORIZED INDICATOR

COX *Flow Measuring Systems* are in use in many aircraft and missile industry laboratories. We welcome the opportunity to tell you more about them.

DIAL INDICATOR

Write for our new bulletin No. 2027. *Cox Instruments Division, George L. Nankervis Company, 15400 Fullerton Avenue, Detroit 27, Michigan.*

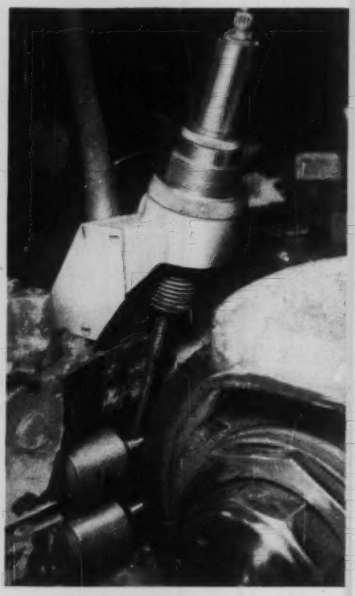
COUNTER

Precision Instruments Since 1912

7391

COX Instruments

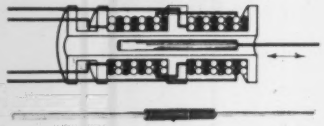
CIRCLE 107 ON READER-SERVICE CARD



± 3 micron sensitivity in this typical differential transformer application. The ATCOTRAN® differential transformer measuring probe continuously senses amount of stock removed from work piece during this grinding operation, stops feed above established grinding dimensions, and simultaneously starts timed dress-up. Automatic cut-off at end of dress-up actuates withdrawal and stops spindle motor. Probe tip may be equipped with diamond point, roller, shoe or other work contact element suitable for position, thickness or tolerance measurement. Displacement measuring range is from 0 to 0.025 inches.

SYSTEM-PROVED STANDARD ATC DIFFERENTIAL TRANSFORMERS

INCREASE SENSITIVITY, SIMPLIFY CIRCUIT DESIGN



WHAT IS A DIFFERENTIAL TRANSFORMER? An electromechanical device which continuously translates displacement or position change into linear AC voltage.

WHAT ARE ITS ADVANTAGES? It is frictionless, has infinite resolution, high signal to noise ratio, low null voltage, unaffected by wide temperature ranges or radiation exposure, linear to 1/10th of 1%, small in size and weight.

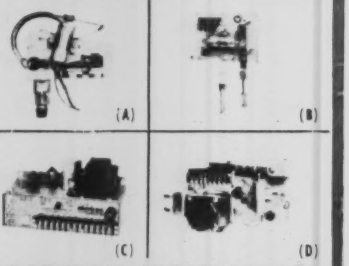
WHERE ARE ATC DIFFERENTIAL TRANSFORMER SYSTEMS IN USE? In numerous industrial and military applications where sensitivity, economy, and consistent performance are demanded in a control or indicating system.

HOW CAN I FIND OUT HOW DIFFERENTIAL TRANSFORMERS WILL HELP ME?

Send for ATC's free 32 page "Handbook of Linear Transducers," which gives theory, characteristics, curves, schematics and application data.

HOW CAN I EXPERIMENT WITH DIFFERENTIAL TRANSFORMERS?

ATC's Experimental Kit offers all essentials for experimentation and development: technical data, seven transformers (linear range ± 0.01 to ± 2.5 inches), flexure plate and mounting clamp, and demodulator.



ATCOTRAN COMPONENTS

(A) Pressure Pick-up measures and controls flow of gas or liquid.
(B) Edge Guide senses edge position of continuous strips.
(C) Amplifier operates from input of any Atcotran sensing device.
(D) Servo Mechanism to position remote indicators with precise accuracy.

atc

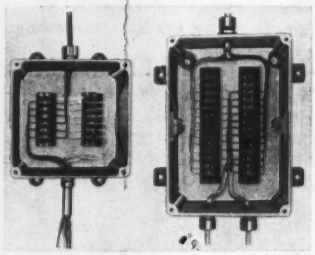
AUTOMATIC TIMING & CONTROLS, INC.
KING OF PRUSSIA, PENNSYLVANIA
A SUBSIDIARY OF SAFETY INDUSTRIES, INC.

CIRCLE 108 ON READER-SERVICE CARD

NEW INSTRUMENTS

TERMINAL BOXES

New line of weatherproof Multi-Junction Thermocouple Terminal Boxes built of cast iron or sheet steel,

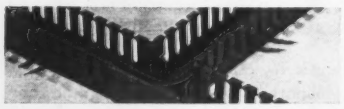


with neoprene gasketed covers, provides protected termination of from 6 to 100 thermocouple circuits. Sizes range from 8" x 8" x 4" to 30" x 24" x 8".—*Thermo Electric Co., Inc., Saddle Brook, N. J.*

CIRCLE 217 ON READER-SERVICE CARD

PLASTIC DUCT FITTINGS

New molded one-piece Corner Junctions, "T" Junctions, and Straight-Thru Couplings for wiring duct can be assembled readily into duct systems. Fittings can be snapped into

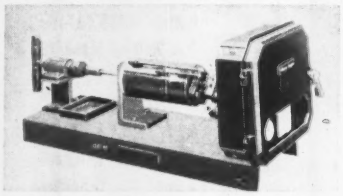


place after duct is installed. Both corner and "T" sections and couplings have side flanges allowing ⅜" deviation in duct length which eliminates the need for precision cutting. Molded from flame-retardent plastic with no fibrous filler.—*Panduit Corp., Dept. IAN,* 14461 *Waverly, Midlothian, Ill.*

CIRCLE 218 ON READER-SERVICE CARD

METERING PUMP

New pneumatically controlled Servo-Gauge Metering Pump is an explosion-proof unit. Operating power can be either air or gas of 90 psig, and metering adjustments can be made during operation either manual-

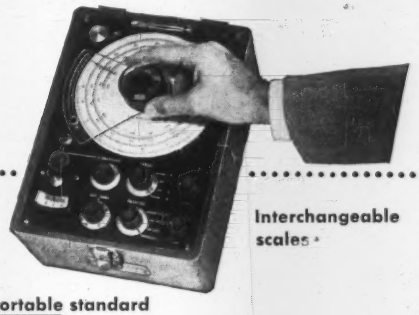


ly or automatically by a pneumatic transmitter. Capacities range from 0.12 to 82.5 gph with discharge pressure ranges up to 5,000 psig. Controlled discharge is linearly proportional to 3-to-15-psig signal.—*Associated Control Equipment, Inc., Box* 136, *Coraopolis, Penna.*

CIRCLE 219 ON READER-SERVICE CARD

Calibrate Pyrometers

. . . Measure Temperatures



Read temperatures or millivolts directly

Interchangeable scales

A portable standard

The Pyrotest checks recorders, controllers and thermocouples . . . measures temperatures. It is a precision signal source, simulating thermocouple temperatures, for checking other potentiometers. Built-in "run up" permits checking of millivoltmeters.

19 different stock scales will fit one Pyrotest! Scales interchange in seconds. °F. or °C. calibrations for all types of thermocouples supplied. Scales directly read temperatures or millivolts.

Features include cold junction compensation, high accuracy, built-in standard cell. Request Bulletin 9B for complete specifications.

TECHNIQUE

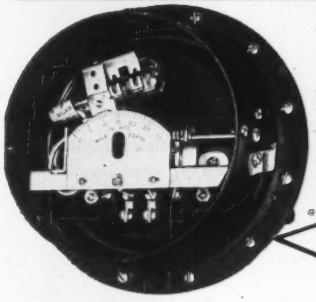
TECHNIQUE ASSOCIATES

A Division of Duncan Electric Co., Inc.

P. O. BOX 91 • INDIANAPOLIS 6, INDIANA

CIRCLE 109 ON READER-SERVICE CARD

LOW PRESSURE DIAPHRAGM CONTROL



FOR GASES OR AIR

FM APPROVED

This FM approved (Mercoid Type PG) control can be used three different ways; for positive pressure; negative pressure (vacuum); for differential pressure or vacuum.

OPERATING RANGE 1.0" to 30.0" (H_2O)
FIXED DIFFERENTIAL (Sensitivity)
When operating point is set at

Low	Med.	High
0.6"	0.8"	1.0"

MAXIMUM PRESSURE 20 psig

Equipped with Fairprene diaphragm, external adjustments, hermetically sealed mercury switch—case made of heavy gauge steel (NEMA 1)

Available fully automatic or semi-automatic with manual reset.

Write for Bulletin PG to

MERCOID *APPROVED CONTROLS* **THE MERCOID CORPORATION** 4201 Belmont Ave., Chicago 41, Ill.

CIRCLE 110 ON READER-SERVICE CARD

CAMBRIDGE GAS ANALYZERS

The Cambridge Recording Gas Analyzer continuously analyzes and records as many as six constituents of a gas. Eliminates intermittent, slow and expensive manual gas analysis. Accurate . . . Sensitive . . . Simple. No moving parts; utilizes thermal conductivity principle.

Makes possible substantial savings in the operation of kilns, production of inert gases, and in metallurgical, petroleum, and other chemical processes. Single- and Multi-point instruments are available for a wide variety of applications.

Send for literature mentioning application

CAMBRIDGE INSTRUMENT COMPANY, INC.

3554 Grand Central Terminal, New York 17

Pioneer Manufacturers of

PRECISION INSTRUMENTS

CIRCLE 111 ON READER-SERVICE CARD

A STANDBY ENGINE *Automatically Controlled* by SYNCHRO-START CAN PROTECT YOU FROM MAIN POWER FAILURE

In A Matter of Seconds power can be re-established by a standby engine equipped with Synchro-Start controls.

Since 1932 Synchro-Start has been manufacturing dependable controls that are operating standby power engines to provide protection for . . .

- HOSPITALS
- AIRPORTS
- PUMPING STATIONS
- PIPE LINES
- ELECTRIC PLANTS
- BRIDGES
- COMMUNICATIONS
- MILITARY CENTERS

AND MANY OTHERS

These controls are in world-wide use plus a variety of other controls manufactured for specific engine operations.

For complete information on your requirement send engine data and desired operational control.

SYNCHRO-START PRODUCTS, INC.

Since 1932

8151 NORTH RIDGEWAY AVENUE • SKOKIE, ILLINOIS

CIRCLE 112 ON READER-SERVICE CARD

TRANSISTORIZED TIMER

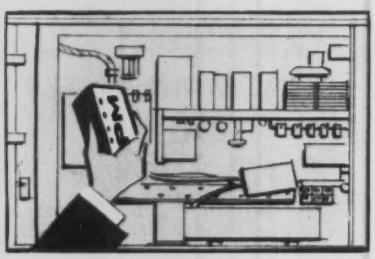
CVR-610

INSTRUMENT POWER SUPPLY

replaces short-life dry cells in recording and controlling instruments with dependable long-life power supply

Tops in the industry! A direct replacement for #6 or 4FH battery. Features long-life semi-conductors, high temperature operation-stability. Output voltage variation less than 0.1% with line variations of 105-125 volts and frequency variations of 50-60 cycles. **$62.50**

Unconditionally Guaranteed for 10 Years



● **INSTALL THE CVR-610 WITHOUT TOOLS OR INSTRUMENT MODIFICATION** . . . it's a perfect fit every time with a minimum of effort. For Brown, Leeds & Northrup, Minneapolis Honeywell and others. You can depend on **PM.**

PM

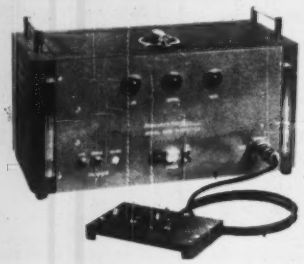
PERFORMANCE MEASUREMENTS COMPANY

15301 W. McNichols, Detroit 35, Mich.

CIRCLE 113 ON READER-SERVICE CARD

RESISTANCE LIMITS BRIDGE

New Model 8516 Pilotal Ohmeter indicates on pilot lamps whether resistance is within predetermined limits. Range of the standard model is

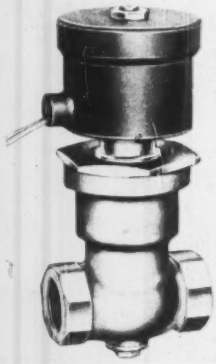


3.75 to 4.00 ohm. Resistance ranges of 0.1 and 1 million ohm can be supplied. Accuracy on the standard instrument is better than 0.05 ohm.—*Associated Research, Inc., 3777 W. Belmont Ave., Chicago 18, Ill.*

CIRCLE 220 ON READER-SERVICE CARD

SOLENOID VALVES

New 30,000-Series full-ported, direct-lift Solenoid Valve with port sizes from ¼" to 3" and pressure range



from zero to 3,000 psig features the new Uramic solenoid that assures reliable operation regardless of line pressures.—*Atkomatic Valve Co., Inc., 545 West Abbott, Indianapolis, Ind.*

CIRCLE 221 ON READER-SERVICE CARD

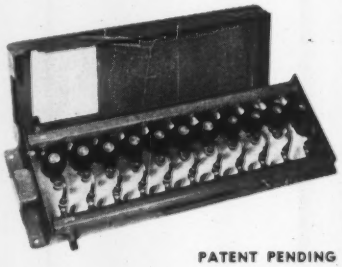
COLORED MAGNETIC TAPE

New Magnetic Recording Tape in three different colors (blue, green, and oxide brown) for use by studios to distinguish between categories of recorded material, between master and non-master tapes, or between material recorded at different levels or equalizations, has the same characteristics and sells at the same price as standard-brown 1½ mil, ¼" plastic-base Audiotape 2551. It is available on 10½" professional reels as well as other sizes.—*Audio Devices, Inc., 444 Madison Ave., New York 22, N. Y.*

CIRCLE 222 ON READER-SERVICE CARD

DIGITAL FINAL CONTROL ELEMENTS FOR AUTOMATION

- Digital Control Valves
- Digital Regulators
- Digital Actuators
- Digital Pumps & Compressors



PATENT PENDING

DIGITAL CONTROL VALVE

A number of these valves are in service operating directly from Digital Computers, Flow Rate Range 0-2048 cc/m in Icc/m Increments.

ADVANTAGES:

- Operates Directly From Digital Computers without any conversion Equipment.
- Perfect Repeatability and Stability.
- Precision Accuracy
- Instantaneous Response Throughout Range.
- No Complex Servo Devices or Adjustments Required.

FERGUSON, HILLE & ASSOC. INC.

542 S. DEARBORN ST.

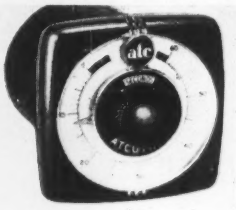
CHICAGO 5, ILLINOIS

WAbash 2-1808

CIRCLE 114 ON READER-SERVICE CARD

TRANSISTORIZED TIMER

New Series-308 Transistorized Timer, designed specifically for industrial applications, features heavy duty DPDT control contacts rated 15 amp at 115 vac, 10 amp at 230 vac,

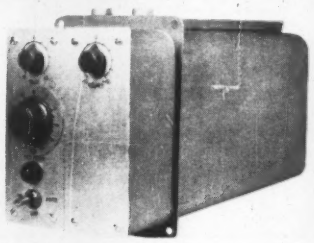


and 4 amp at 115 vdc. A filtered power supply feeds an RC network working through a transistor to operate a relay at the end of the timing cycle, providing maximum life expectancy and simplicity. No warm up time is required before energizing the timer. Dial ranges are: 0.02 to 1 sec; 0.05 to 5 sec; 0.125 to 15 sec; 0.25 to 30 sec; 0.5 to 60 sec; and 1 to 120 sec.—*Automatic Timing & Controls, Inc., King of Prussia, Penna.*

CIRCLE 223 ON READER-SERVICE CARD

TRANSISTORIZED TIME-PROPORTIONING CONTROLLER

New time-proportioning On-Off Controller with adjustable set point and gain, and manual reset adjustment unit which plugs into the re-

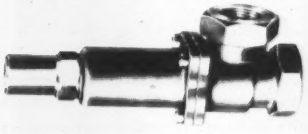


corder, uses solid-state components throughout, and takes a-c or d-c inputs. Modular units can also be panel mounted. Details in Products Specification E93-1.—*Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, Ohio.*

CIRCLE 224 ON READER-SERVICE CARD

BACK PRESSURE VALVES

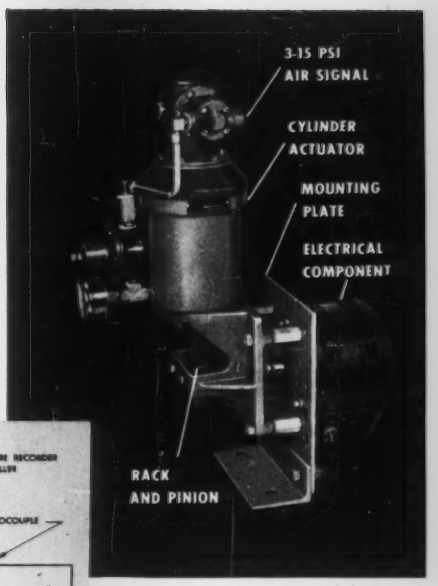
Two new series of Back Pressure Valves Type K-10 and K-20 for use on tool lubrication machines, diesel engine lubrication, oil burner feeds

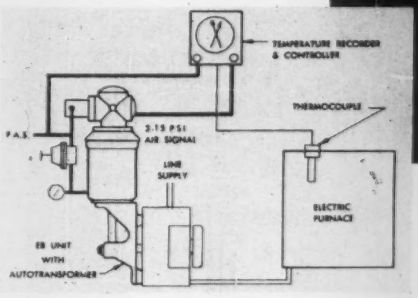


and oil cooling units, feature a balanced-piston design in the Type K-10 series and an aspirating nozzle in the Type K-20 series.—Bulletin 3-9 gives details.—*Cash-Acme, Box 191, Decatur, Ill.*

CIRCLE 225 ON READER-SERVICE CARD

REGULATE VOLTAGE, CURRENT, RESISTANCE, INDUCTANCE, OR CAPACITANCE





Quality control in heat treating and other exacting temperature control applications is vastly improved by using a Conoflow Model EB with a variable autotransformer.

AUTOMATICALLY-PNEUMATICALLY

CONOFLOW MODEL EB CURRENT CONTROLLER

The Model EB is a unique final control element—a Conoflow exclusive. Essentially, it is a pneumatic-electric transducer, consisting of a cylinder actuator, a rack and pinion mechanism, and an electrical component such as a rheostat, autotransformer or potentiometer. The cylinder receives a 3-15 psi instrument signal and produces a rotary motion (to 360°) which precisely positions the electrical device, affording automatic control of any electrical value.

Model EB Current Controllers are available from Conoflow in over 200 different combinations of electrical components. These assemblies are designed to handle a wide variety of control applications more efficiently and more economically than possible by manual operation. A few are:

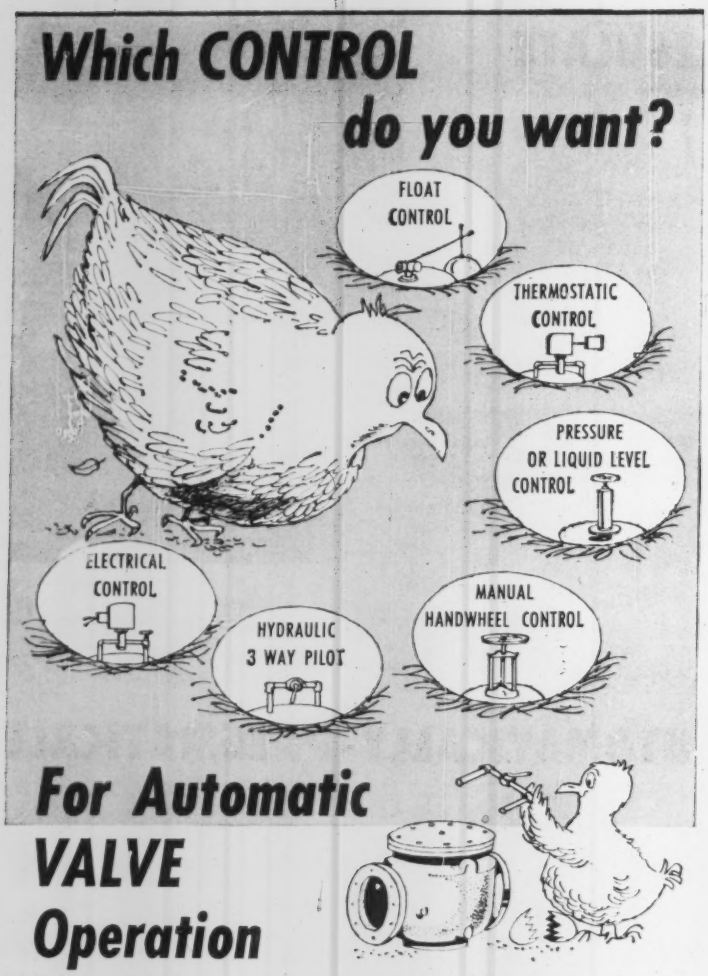
- CONSTANT PRESSURE
- PROPORTIONAL FLOW
- LIQUID LEVEL
- MACHINE TOOL SPEED
- CONVEYOR CONTROL
- HEAT TREATING
- CONSTANT TEMPERATURE
- BOILER FEED WATER CONTROL
- REWIND CONTROL
- CONSTANT FLOW
- STOKER FEED CONTROL
- HUMIDITY CONTROL

For additional information on the Model EB Current Controller, write to Conoflow Corporation, 2100 Arch Street, Philadelphia 3, Pa. Ask for Bulletin EB-3.

CONOFLOW CORPORATION
FOREMOST IN FINAL CONTROL ELEMENTS

SUBSIDIARY WALWORTH

CIRCLE 115 ON READER-SERVICE CARD



Designed to automatically operate with any control, G-A cushioned valves are available in sizes 2" thru 30" for special fluid control applications. You should have our complete catalog on file—write today.

Golden Anderson Valve Specialty Company
1210 RIDGE AVENUE, PITTSBURGH 33, PA.

Designers and Manufacturers of VALVES FOR AUTOMATION

CIRCLE 116 ON READER-SERVICE CARD

GLASS CYLINDERS
RODS · TUBES
CIRCLES & SPECIAL SHAPES

Experimental and Production Blowing
Your Inquiries Invited.

FABRICATED and CUT to Your SPECIFICATIONS

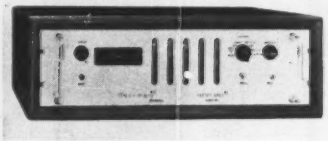
Glass Tubes and Rods for Scientific Use—Lamps, Furniture, Lighting & Decorative Fixtures—Display Domes—Contract Cutters of Tube and Rod.

CRYSTAL GLASS TUBE & CYLINDER CO.
7318 South Chicago Ave. • Chicago 19, Ill.

CIRCLE 117 ON READER-SERVICE CARD

FREQUENCY COUNTER

New transistorized Frequency Counter indicates speed, flow or pressure in any desired units—such as rpm, gps or psi from a conventional digital-transducer input signal. Con-

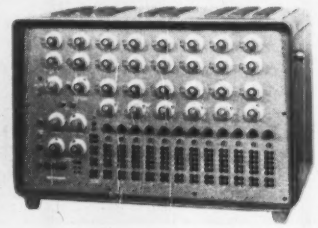


version to convenient units is made by a counting interval variable in 10u sec steps from 10u sec to one full second. Frequency counting range is 10 cps to 200 kc. The counter also makes extremely accurate period measurements by timing the duration of from 1 to 100,000 cps in 10u sec units. The internal time standard has a stability of 3 parts in 10^7 per day at constant temperature.—*Berkeley Div., Beckman Instruments, Inc., 2200 Wright Ave., Richmond 3, Calif.*

CIRCLE 226 ON READER-SERVICE CARD

ANALOG COMPUTER

New Model AR-2 Analog Computer developed by Guttinger Industries in Switzerland measures only 35½" x 21" x 23". Furnished complete with 12 amplifiers, 16 potentiometers, a



pulse generator, and a stepping function generator, six of the amplifiers can be used as integrators (with three different ratios of integration). The solution to physical and mathematical problems appears as a time-variable voltage curve that can be viewed on any d-c or a direct-writing oscilloscope. An x-y plotter can also be used to plot one variable against another.—*Boonshaft and Fuchs, Inc., Hatboro Industrial Park, Hatboro, Penna.*

CIRCLE 227 ON READER-SERVICE CARD

GENERAL PURPOSE COMPUTER

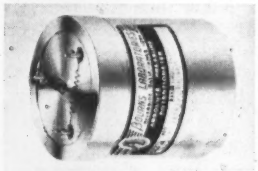
New Model 1604, a fully-transistorized large-scale stored-program general-purpose Digital Computer costs "a fraction of computer of comparable performance offered in the U. S. today." Transistorized printed-circuit modules are used throughout; of these pluggable cards, 13 types are logical elements and 12 types are special magnetic core drivers, etc. The basic circuit is repeated 9000 times

in the computer. A total of 7000 printed circuit cards are used. Features include: 32,768 48-bit words of magnetic core storage, parallel mode of operation, single address logic, 2 instructions per 48-bit word, 6 index registers, indirect addressing.—*Control Data Corp., 501 Park Ave., Minneapolis 15, Minn.*

CIRCLE 228 ON READER-SERVICE CARD

PRESSURE TRANSDUCERS

New Models 409 and 509 Pressure Transducers, designed primarily for the aircraft and missile industry in explosive atmospheres, meet MIL-E-5272A specs. Model 409 is for absolute

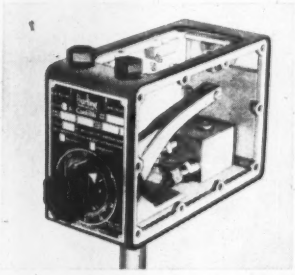


pressure, for linear pressure, or altitude outputs, while Model 509 is the differential pressure version for outputs which are linear with pressure or air speed. Specifications are—Range: 0-2 to 0-100 psi; resistance: 1 k to 15 kohm; resolution: 0.2 to 0.5%; linearity: ±0.6%; hysteresis: 0.4 to 0.5%; power rating: 0.8 w at 45°C. Bulletin on Model 409 available. —*Bourns, Inc., Box 2112, Riverside, Calif.*

CIRCLE 229 ON READER-SERVICE CARD

PNEUMATIC TEMP CONTROL

New Model OA, essentially a temperature transmitter, working on the differential expansion principle pro-



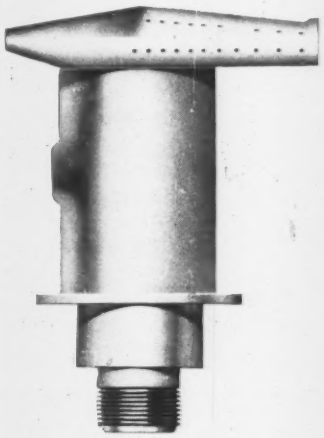
vides air pressure proportional to temperature and is for direct operation of air-operated diaphragm valves, motors, dampers, or similar equipment. Bulletin 152 gives details.—*Burling Instrument Co., Chatham, N. J.*

CIRCLE 230 ON READER-SERVICE CARD

CAN BE OBTAINED
THROUGH THE USE OF REC's
ALL WEATHER MODEL 102 Series
TOTAL TEMPERATURE PROBE.

FAST AND ACCURATE . . . THE 102U HAS THE ABILITY TO MEASURE TOTAL TEMPERATURE WHILE DEICING HEAT IS CONTINUOUSLY APPLIED.

BENEFICAL USES . . . . .



Model 102 U
(ONE HALF SIZE)

- To select engine power settings and flight altitude for best economy and safety.
- To monitor engine performance—when used in combination with engine speed and pressure ratio. (to detect engine malfunction)
- To calculate true airspeed (in combination with Mach number) for air navigation.
- To indicate total temperature, for miscellaneous purposes. For example, to indicate icing temperatures.
- To locate jet stream.

FOR FURTHER INFORMATION WRITE FOR BULLETIN NO. 7597

ROSEMOUNT ENGINEERING COMPANY
4900 WEST 78th ST. MINNEAPOLIS 24, MINNESOTA

REC®

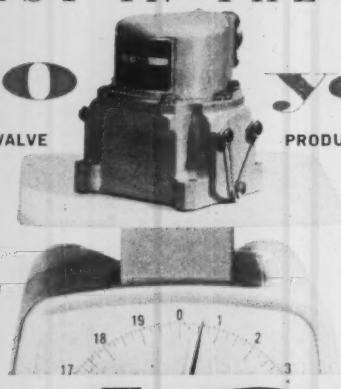
CIRCLE 118 ON READER-SERVICE CARD

MIDWESTERN MI INSTRUMENTS

LIGHTEST IN THE FIELD!

AND BACKED BY 10 years

OF SERVOVALVE PRODUCTION EXPERIENCE



MI SERIES 40 SERVOVALVES

ONLY 9.5 OUNCES

DEPENDABLE

Large control orifices, clearances, and high driving forces (½ system pressure with 10% rated current) insure long life and maximum reliability.

MECHANICAL FEED BACK
LOW HYSTERESIS: 2%

Featuring simplified design, the Midwestern Model 40 Series Servovalves have been tooled for production to meet existing and anticipated reliability requirements of military applications. Special effort has been made to lighten weight, improve hysteresis, decrease leakage and reduce susceptability to oil contamination.

Various configurations of the Model 40 are available for three-way or four-way service.

DYNAMICS: Amplitude — 3 db max. at 150 cps.
Phase — 90° at 150 cps. max.
TORQUE MOTOR: Dry gap and coils, hermetically sealed.
LEAKAGE: External, none. Internal, .09 gpm max. (to drain)
RATED FLOW: To 5.0 gpm at 1000 psi valve drop.

WRITE FOR MORE DETAILS! MI PRODUCES:

Oscillographs
Galvanometers
Amplifiers
Bridge Balance Units
Discriminators
Voltage Controlled Oscillators
Magnetic Tape Recorders
Magnetic Recording and Reproducing Heads
Power Supplies
Current Sources
Data Repeaters
Servovalves
Linear Displacement Solenoids
Torque Motors
Servo Amplifiers
Precision Analog Recording Systems
Aircraft Data Acquisition Recorders
Complete FM Ground Station Telemetering Systems

MIDWESTERN INSTRUMENTS

41ST & SHERIDAN RD./P. O. BOX 7186/RI 7-1331/TWX: TU 849/TULSA, OKLA.

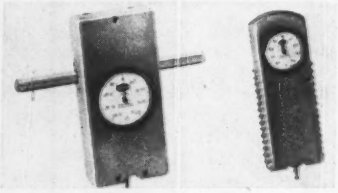
also manufacturers of Magnecord fine tape recording instruments

CIRCLE 119 ON READER-SERVICE CARD

NEW INSTRUMENTS

PUSH-PULL GAGES

New line of dial Push-Pull Gages tests both compression and extension from the same end of the instrument with an accuracy of ½ of 1% of maximum capacity. Two models are

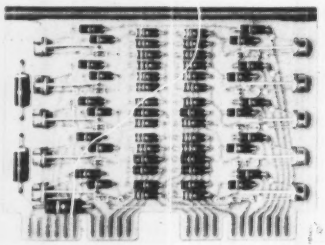


available. Model PPL, with six units of varying capacities of from 1 to 50 lb; and Model PPH, with four units with capacities of from 50 to 250 lb. —*John Chatillon & Sons, 85 Cliff St., New York 38, N. Y.*

CIRCLE 231 ON READER-SERVICE CARD

NIXIE INDICATOR DRIVER

New Nixie Indicator Driver, Model NX-101, a BCD-to-decimal converter that accepts the 8-4-2-1 binary decimal code from a BD-101, or equivalent

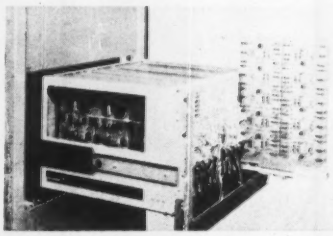


decimal counter, and applies appropriate drive signals to the corresponding cathode of a Nixie tube, has ten stages consisting of an NPN transistor and a resistor decoder.—*Computer Control Co., Inc. 983 Concord St., Framingham, Mass.*

CIRCLE 232 ON READER-SERVICE CARD

MILLIMICROSEC QUANTIZER

New fully-transistorized Electronic Quantizer, Model LFQ-20, accepts time-varying input signals and reads

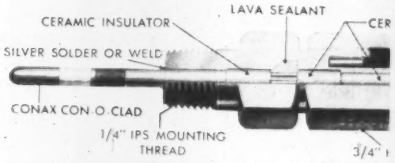


out the time of each interval in digital code with an accuracy of one part in 10^7 per day. Resolving time is 20 musec.—*Computer Equipment Corp., 1931 Pontius Ave., Los Angeles 25, Calif.*

CIRCLE 233 ON READER-SERVICE CARD

INSULATED THERMOCOUPLES

New line of Con-O-Clad mineral-insulated Thermocouples features flexibility that permits bending into unlimited configurations; high temperature range (up to 3,000°F); probes from 0.040" to 0.375" dia sheath;



fast response rate; wires encased by inert minerals in air tight chamber; shock and vibration proof; and corrosion resistance from many sheath metals. Iron-Constantan, Copper-Constantan, or Chromel-Alumel are standard. Platinum/platinum + 10% rhodium, and platinum/platinum + 13% rhodium calibrations are also available.—*Conax Corp.*, 2300 *Walden Ave., Buffalo* 25, *N. Y.*

CIRCLE 234 ON READER-SERVICE CARD

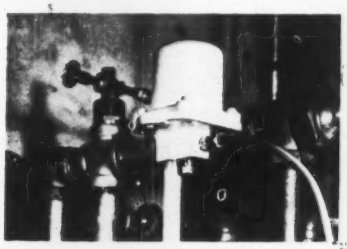
MAG-TAPE READER/RECORDER

New high-speed Recording System "Dacom" (for Datascope Computer Output Microfilmer), "reads" the magnetic tapes from electronic computers, displays the corresponding letters or numbers on the face of a cathode-ray tube, and a special camera continuously photographs the face of the tube to put a complete page on microfilm. Speed is 16,500 characters/sec. Up to 66 lines of 130 characters can appear as a page, and these are microfilmed at more than two frames/sec. The system can record 6,900 lines/min or more.—*Eastman Kodak Co.*, 343 *State St., Rochester* 4, *N. Y.*

CIRCLE 235 ON READER-SERVICE CARD

RESISTANCE PRESS DETECTOR

New Resistance Pressure Detector, Model 328 RPD, for gases, fluids, or vapors, converts pressure directly to an electrical resistance. No amplifier



is needed. Ranges are from in-Hg to 3000 psig. Normally mounted in a pressure detector head to protect it and the lead wires from damage, it has a ¼" standard pipe thread inlet. Bulletin 3051 gives details.—*Instrument Div., Thomas A. Edison Industries, McGraw-Edison Co., West Orange, N. J.*

CIRCLE 236 ON READER-SERVICE CARD

WHEN YOU HAVE
extraneous common mode signals

AND WANT TO MEASURE
0.1 to 100 millivolts full scale

AND THEN AMPLIFY

CHOOSE THE NEW HONEYWELL D-C AMPLIFIER

AccuData II

wide-band differential all-transistor D-C Amplifier for strain gages and thermocouples

- **Full Scale Input:** Unbalanced: ±100 μv to ±100 mv Differential: ±3 mv to ±100 mv Open Loop: Below drift level
- **Full Scale Output:** ±2v at 50 ma, dc to 10 kc
- **Frequency Response:** to 20 kc
- **Output Impedance:** Less than 0.5 ohm at dc on all ranges
- **Input Impedance:** Unbalanced 3 to 100 mv ranges; greater than 20 megohms in parallel with 350 micromicrofarads. Differential: Greater than ±2 megohms
- **Equivalent D-C Input Drift:** Less than 2 μv/10°F ambient temp change on 0.1 to 30 mv input ranges
- **Equivalent Input Noise:** 4μv peak-to-peak on 100 μv to 300 μv range (0-10 cps). 8μv rms on 10 to 30 mv ranges (0 to 100 kc)
- **Common Mode Rejection:** 200,000 at 60 cps on 3 to 30mv ranges

The new Honeywell AccuData II is a completely transistorized D-C Amplifier designed for use in high accuracy data handling systems as a wide-band pre-amplifier for strain gages and thermocouples. Its output can be fed to electronic or electromechanical analog-to-digital converters and simultaneously recorded on galvanometer oscillographs or magnetic tape. Either differential or single-ended input modes can be selected by an eleven position range switch. This switch changes the gain in three-to-one steps. Intermediate gains with high resolution are provided by a ten-turn potentiometer. Write for AccuData II Bulletin to Minneapolis-Honeywell, Dept. 50, Boston Division, 40 Life Street, Boston 35, Mass.

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First in Control

CIRCLE 120 ON READER-SERVICE CARD

how to apply low cost VARIABLE SPEED to your product

This 16-page catalog covers a wide range of practical information on how to get the most from your electric motors . . . variable speed, instant control, reversing, increasing torque, clutching, presetting RPM's, remote control, measuring torque . . . and other items. It also illustrates and describes Zero-Max variable speed controls for fractional horsepower motors.

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CIRCLE 121 ON READER-SERVICE CARD

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FOR COMPLETE INFORMATION ON PANDUIT-ENGINEERED WIRING COMPONENTS, WRITE . . .

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CIRCLE 122 ON READER-SERVICE CARD

new plants and mergers

SUPREME ELECTRONICS CORP., a subsidiary of HICKOK, has broken ground for a 25,000-sq-ft addition to its Greenwood, Miss. plant.

BENSON-LEHNER and DOCUMENTATION, INC. have merged. The latter will be operated as a wholly-owned subsidiary.

people in the news

HICKOK Electrical Instrument Co. has elected *Paul Willour* vice president-treasurer and *Robert L. Purcell* assistant secretary-treasurer.

GENESYS CORP. announces appointment of *Robert M. Cornforth* as sales manager.

STROMBERG-CARLSON—San Diego, announces that *George W. McGinley* has been appointed sales manager.

Morehouse ANNOUNCES...

A BALANCING INSTRUMENT WITH A NEW STANDARD OF PERFORMANCE

Recognized for its outstanding accuracy and versatility, the Morehouse Calibration and Weighing System Balancing Instrument has undergone a design change which adds new standards of stability and performance. An extremely sensitive miniature cam, spring loaded for positive performance, replaces a potentiometer as the zero adjustment device. No phase relationship difficulties are possible and readings are direct and simple.

In calibrating load cells, dynamometers, thrust stands, testing machines, and other weighing systems, the Morehouse Balancing Instrument can be teamed with various capacity Morehouse Load Rings to give a broad calibration range. A vacuum tube is used with the instrument and operates on 110 volts.

Send today for our Bulletin 169 and data on this new Balancing Instrument.

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CIRCLE 123 ON READER-SERVICE CARD

P. Willour
Hickok

R. L. Purcell
Hickok

R. M. Cornforth
Genesys

G. W. McGinley
Stromberg

C. E. Mathewson
Daystrom

R. E. Clarridge
G. E.

DAYSTROM, INC. has named *Clifford E. Mathewson* manager of advertising and public relations for the Control Systems Division.

GENERAL ELECTRIC CO. announces that *Ralph E. Clarridge* has been appointed manager of the measurements laboratory in West Lynn, Mass.

ELECTRONIC ASSOCIATES has named *William K. Kindle* chief engineer.

THOMAS & SKINNER announces that *Edward R. Cronk* has joined the company as chief product engineer.

PANELLIT has appointed *Stanley Knoblock* chief engineer of its eastern division with headquarters in New York.

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We offer to the Instrument Maker Charts for all methods of Recording: Pen, Ball Point, Electrical, Thermal, Pressure and Metallic Stylus.
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CHARTS INCORPORATED
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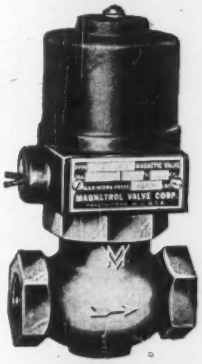
Costly
Flow Failures

Magnatrol
SOLENOID VALVES



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Catalog containing complete specifications mailed upon request.

Magnatrol **VALVE Corp.**
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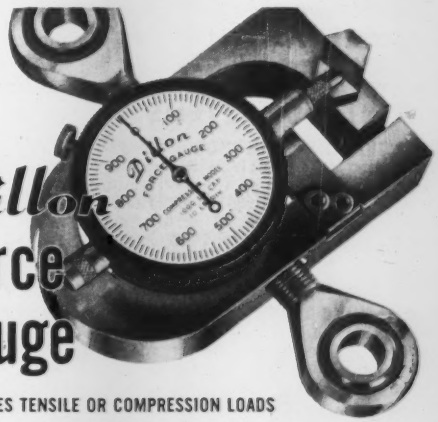
NEW JERSEY

CIRCLE 124 ON READER-SERVICE CARD



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CIRCLE 125 ON READER-SERVICE CARD

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ANALOG COMPUTER ENGINEER

B S Mechanical Engineer, Aero Engineer, Physics M S preferred. At least three years of experience in the use of analog computers for studying dynamic problems. Applications are in the field of aircraft and missile propulsion control systems, dynamics of landing gear systems, hydraulic and pneumatic devices and heat transfer.

The computer facilities include a repetitive analog, a precision real time analog and digital computers.

Salary commensurate with experience. Comprehensive benefit program is offered including: moving and transportation allowances, group insurance, vacations, and tuition assistance for advanced degrees at the University of Notre Dame.

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Data Systems can pull the stopper. Computer design and development engineers are needed to work on a variety of commercial projects. These include automatic industrial controls, special purpose digital data processing equipment, and advanced mark sensing systems involving high speed paper handling devices. Expansion of the department to twice its present size in the next six months is creating plenty of room for fast advancement. Pay schedules are excellent. Working conditions are ideal. A new facility is planned for the Newport Beach (Southern California) area.

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new literature

CONTROL SYSTEMS

STRIP TENSION CONTROL. 4-page Performance Report S11-1 outlines the results achieved by a Pennsylvania Steel Mill in minimizing strip breakage on three continuous annealing lines.—Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, Ohio.

CIRCLE 237 ON READER-SERVICE CARD

TEMPERATURE CONTROLLERS. 2-page catalog sheet describes surface mounting temperature controllers, Series 30000.—Fenwal Inc., Pleasant St., Ashland, Mass.

CIRCLE 238 ON READER-SERVICE CARD

VALVES

PRESSURE REDUCING VALVES. 4-page Bulletin 56C illustrates with dimensions and describes operation, installation, etc. of Atlas Type B pilot-operated reducing valves.—Atlas Valve Co., 280 South St., Newark 5, N. J.

CIRCLE 239 ON READER-SERVICE CARD

STANDARD VALVES & FITTINGS. 16-page catalog tabulates with dimensional data, cross-sectional drawings, etc. standard valves and fittings for 30,000-psi and 60,000-psi service.—High Pressure Equipment Co., Inc., Erie, Pa.

CIRCLE 240 ON READER-SERVICE CARD

CONTROL VALVES. 24-page Condensed Bulletin 800 illustrates and describes with applications line of diaphragm control valves.—Warren Engrg. Co., Route 24, Broadway, N. J.

CIRCLE 241 ON READER-SERVICE CARD

TEMPERATURE

THERMAL ELEMENTS. 29-page booklet "The Story of the Spencer Disc, 3rd Edition," describes origin and operation of snap-action disc type thermal elements.—Metals & Controls, Div. of Texas Instruments Inc., 34 Forest St., Attleboro, Mass.

CIRCLE 242 ON READER-SERVICE CARD

RECORDING PYROMETER. 4-page reprint entitled "Recording Optical Pyrometer" describes a recording pyrometer.—George A. Philbrick Researches, Inc., 285 Columbus Ave., Boston 16, Mass.

CIRCLE 243 ON READER-SERVICE CARD

TEMPERATURE CONVERSION CHART. 2-side ease-to-read chart converts F to C and C to F degrees. Reverse side gives differences between wet- and dry-bulb temperature.—Electric Hotpack Co., Inc., Dept. 33, Cottman and Melrose, Phila. 35, Pa.

CIRCLE 244 ON READER-SERVICE CARD

FLOW, LEVEL

LOW-COST ROTAMETER. 2-page Specification Sheet DS-130-1 describes and illustrates with dimensions a new, low-cost flow indicator and alarm.—Brooks Rotameter Co., Hatfield, Penna.

CIRCLE 245 ON READER-SERVICE CARD

GAS AND LIQUID FLOW. 8-page Short Form Catalog describes the entire line of Cox Instruments.—Cox Instruments Div., of the George L. Nankervis Co., 15300 Fullerton, Detroit 27, Mich.

CIRCLE 246 ON READER-SERVICE CARD

LEVEL CONTROL. 4-page Bulletin RF-5914 contains illustrations and descriptions of probes and accessories for capacitance-type level control instruments.—Robertshaw-Fulton Controls Co., Aeronautical and Instrument Div., Santa Ana Freeway at Euclid Ave., Anaheim, Calif.

CIRCLE 247 ON READER-SERVICE CARD

LEVEL DENSITY. 12-page Bulletin PI-959 contains information on all process-industry measurement and control equipment manufactured by company.—Industrial Nucleonics Corp., 650 Ackerman Rd., Columbus 14, Ohio.

CIRCLE 248 ON READER-SERVICE CARD

PROPORTIONING PUMP. 2-page Bulletin Reference No. 1210.20-1 describes and illustrates Model 1210 proportioning pump for treating process water.—B-I-F Industries, Inc., 345 Harris Ave., Providence, R. I.

CIRCLE 249 ON READER-SERVICE CARD

PRESSURE, VACUUM

POTENTIOMETER PRESSURE PICK-UP. 2-page Bulletin 1604 illustrates and describes Model 4-380A potentiometer pressure pickup for missile use.—Transducer Div., Consolidated Electrodynamics Corp., 360 Sierra Madre Villa, Pasadena, Calif.

CIRCLE 250 ON READER-SERVICE CARD

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TEST GAGE. 4-page Bulletin M-28A describes the new Martin-Decker Precision Test Gage with accuracy and sensitivity specs.—Martin-Decker Corp., 3431 Cherry Ave., Long Beach 7, Calif.

CIRCLE 251 ON READER-SERVICE CARD

PRESSURE TRANSDUCERS. 4-page Form SCI-212 describes with pictures and dimensional sketches pressure transducers Series SP2.—Standard Controls, Inc., 1130 Poplar Place, Seattle 44, Wash.

CIRCLE 252 ON READER-SERVICE CARD

LOW PRESSURE CELL. 2-page Bulletin R-10 describes and specifies low pressure cell for differential and absolute pressure measurements.—Computer Components Div., International Resistance Co., 401 N. Broad St., Phila. 8, Pa.

CIRCLE 253 ON READER-SERVICE CARD

VACUUM PUMPING STATION. 4-page Brochure VS-9 describes and illustrates a 2" high-vacuum station.—Veeco Vacuum Corp., Dept. P 1490, 86-P Denton Ave., New Hyde Park, L. I., N. Y.

CIRCLE 254 ON READER-SERVICE CARD

DATA HANDLING

DATA LOGGING SYSTEM. 2-page Data Sheet 2007 describes CANDU-I, a low-priced, accurate, on-the-shelf data system.—Franklin Electronics, Inc., Bridgeport, Penna.

CIRCLE 255 ON READER-SERVICE CARD

DATA HANDLING SYSTEM. 12-page brochure contains a complete description of the Kybernetes Series 2000 Data System.—Controls Div., Hagan Chemicals & Controls, Inc., Hagan Bldg., Pittburgh 30, Pa.

CIRCLE 256 ON READER-SERVICE CARD

ALGEBRAIC COMPILER. 20-page Manual S-520 describes "Act I," a new compiling routine and tranlator for the Royal Precision LGP-30 Electronic Computer.—Royal McBee Corp., Data Processing Div., Port Chester, N. Y.

CIRCLE 257 ON READER-SERVICE CARD

STATIC SWITCHING SYSTEMS. 6-page Bulletin S-8881A describes an advanced method of static control through the use of solid state power/logic switching systems.—Magnetic Amplifiers, Inc., 632 Tinton Ave., New York 55, N. Y.

CIRCLE 258 ON READER-SERVICE CARD

DIGITAL SUBSYSTEMS. 4-page Bulletin RC8.21.9 illustrates with specs functionally-packaged digital subsystems.—Servomechanisms, Inc., Santa Barbara Airport, Bldg. 114, Goleta, Calif.

CIRCLE 259 ON READER-SERVICE CARD

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By 40 year old, well established, midwest medium size industrial instrument manufacturer, to work with manufacturer's reps, nationwide.

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COMPUTERS AND COMPONENTS. Plastic slide affords easy selection of reactance computer; and trimmers, tuners, delay lines, etc.—JFD Electronics Corp., 1462—62nd St. Brooklyn 19, N. Y.

CIRCLE 263 ON READER-SERVICE CARD

AUTOMATIC DATA LOGGERS. 12-page bulletin describes the various types of Data-Master loggers.—Hanson-Gorrill-Brian, Inc., Glen Cove, N. Y.

CIRCLE 264 ON READER-SERVICE CARD

STUDENT COMPUTER. 2-page leaflet describes Microlog Series 2, used as a training instrument for students of analog computer applications.—Ebex Sales Inc., Orem, Utah.

CIRCLE 265 ON READER-SERVICE CARD

MONITORS

ANNUNCIATOR SYSTEMS. 52-page Catalog 100C covers annunciator systems, containing information on the function and their applications.—Panalarm Div., Panellit, Inc., 7401 N. Hamlin Ave., Skokie, Ill.

CIRCLE 266 ON READER-SERVICE CARD

RADIATION LEVEL OF WATER. 4-page bulletin, Form 3038-9, describes scintillation flow water monitor for measuring radioactivity in city water supply and for monitoring waste and sewage.—Victoreen Instrument Co., 5806 Hough Ave., Cleveland 3, Ohio.

CIRCLE 267 ON READER-SERVICE CARD

ANNUNCIATOR. 36-page Catalog 659 gives information on the operation and application of annunciator systems for various industrial uses.—Scam Instrument Corp., 1811 West Irving Park Rd., Chicago 13, Ill.

CIRCLE 268 ON READER-SERVICE CARD

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MGP 3	Plate & Fil.	90028	TF4RX03KB006
MGP 4	Plate & Fil.	90029	TF4RX03LB003
MGP 5	Plate & Fil.	90030	TF4RX03MB004
MGP 6	Plate	90031	TF4RX02KB001
MGP 7	Plate	90032	TF4RX02LB002
MGP 8	Plate	90036	TF4RX02NB003
MGF 1	Filament	90016	TF4RX01EB002
MGF 2	Filament	90017	TF4RX01GB003
MGF 3	Filament	90018	TF4RX01FB004
MGF 4	Filament	90019	TF4RX01HB005
MGF 5	Filament	90020	TF4RX01FB006
MGF 6	Filament	90021	TF4RX01GB007
MGF 7	Filament	90022	TF4RX01JB008
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MGF 9	Filament	90024	TF4RX01JB012
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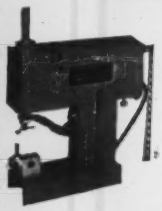
Completely eliminates cut or nicked wire strands since no blades are used. Has High-Low heat control to strip both Teflon and lower-melting plastics. Strips any size wire without adjustment. Designed for high-speed production use. Use either as bench or hand tool. Simple to operate. Insert wire, clamp, then pull. Has adjustable stripping length stop. Sturdy long-life heating elements are easily replaceable. With heavy-duty power supply.

Price $44.50 FOB Altadena, Calif.

Western Electronic Products Co.
655 Colman Street, Altadena, California

CIRCLE 128 ON READER-SERVICE CARD

MINIATURE WELDERS



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Submit parts for free sample welds and ask for data sheet.

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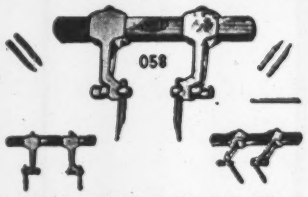

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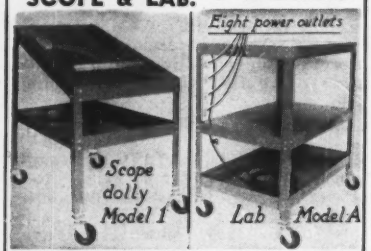

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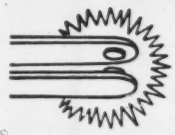

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NEW LITERATURE

GAGING, TESTING

PIPE WALL GAGE. 4-page Booklet 13-200 describes XactRay, a non-contact x-ray device for precise measurements of metallic and non-metallic pipe wall thickness.—Daystrom-Weston Sales Div., 614 Frelinghuysen Ave., Newark 12, N. J.

CIRCLE 269 ON READER-SERVICE CARD

SCIENTIFIC AND TEST INSTRUMENTS. 48-page Condensed Catalog G-10 contains descriptions, illustrations, and specs on d-c amplifiers, data handling systems, lab & calibration instruments, magnetic tape instrumentation, nuclear instrumentation, oscillographs, recorders & indicators, servo components, temperature controllers, and transducers.—Minneapolis-Honeywell Regulator Co., Station M-321, Wayne and Windrim Aves., Phila. 44, Pa.

CIRCLE 270 ON READER-SERVICE CARD

ELECTRONIC GAGING. 12-page brochure, Form 3R3638, describes electronic gaging systems.—Radio Corp. of America, Industrial and Automation Div., 12605 Arnold Ave., Detroit 39, Mich.

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TENSILE TESTING MACHINES. 4-page Bulletin T-859 contains illustrations and descriptions of tensile testing machines including portable and stationary types.—Steel City Testing Machines, Inc., 8817 Lydon Ave., Detroit 38, Mich.

CIRCLE 272 ON READER-SERVICE CARD

NONDESTRUCTIVE TESTING. 4-page bulletin describes range of reliability tests in maker's nondestructive test systems.—Magnaflux Corp., 7300 W. Lawrence Ave., Chicago 31, Ill.

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RELAY CONTROL AMPLIFIER. 4-page Catalog Sec. 90 describes high-gain d-c to a-c relay control amplifier including principles of operation, performance ratings, and applications.—Thermo Electric Co., Inc., Saddle Brook, N. J.

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ELECTRICAL INDICATORS. 4-page Short Form Catalog illustrates and describes many different types of electrical indicating instruments.—Sensitive Research Instrument Corp., 310 Main St., New Rochelle, N. Y.

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PULSE INSTRUMENTATION. 48-page 1959-60 General Catalog contains complete technical data on a broad range of pulse instrumentation, including pulse generators, word generators, time-delay generators, and electronic counters.—Electro-Pulse, Inc., 11861 Teale St., Culver City, Calif.

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WIDE RANGE OHMMETER. 2-page leaflet describes wide range ohmmeter, Model 701, with application and specs.—Mid-eastern Electronics, Inc., 32 Commerce St., Springfield, N. J.

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OSCILLOSCOPES. 16-page Short Form 1959 Catalog contains illustrations and descriptions of a wide variety of oscilloscopes.—Hewlett-Packard Co., 275 Page Mill Rd., Palo Alto, Calif.

CIRCLE 278 ON READER-SERVICE CARD

POWER SUPPLIES

SILICON RECTIFIER POWER SUPPLIES. 4-page Bulletin GEA-6854, describes silicon rectifier power supplies for industrial and utility electrostatic precipitation applications.—General Electric Co., Schenectady 5, N. Y.

CIRCLE 279 ON READER-SERVICE CARD

Ni-Cd BATTERIES. 4-page Bulletin VO-110 describes and lists with specs VO-series button cell batteries.—Alkaline Battery Div., Gulton Industries, Inc., Metuchen, N. J.

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MISCELLANEOUS

EQUIPMENT DESIGN. 4-page bulletin describes engineering facilities for design, fabrication, and process plant service.—Industrial Process Engineers, 6 Lister Ave., Newark 5, N. J.

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ROTARY SWITCH. 2-page bulletin describes the new high precision rotary switch WP-2.—Waters Mfg., Inc., Wayland, Mass.

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TUBE FITTINGS. 4-page Bulletin 4306B1 offers condensed information to help select proper fittings for various service and installation requirements.—Parker Fittings & Hose Div., Parker-Hannifin Corp., 17325 Euclid Ave., Cleveland 12, Ohio.

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PRECISION POSITION INDICATOR. 2-page catalog sheet gives technical details, including dimensional drawings and illustrations, of Series 2600 drum type latitude and longitude precision counters.—Chicago Dynamic Industries, Inc., Precision Products Div., 1725 Diversey Blvd., Chicago 14, Ill.

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GASEOUS CONDUCTION TUBES. 6-page catalog-circular gives complete specifications for stroboscopic tubes, reflective base flashtubes, d-c or battery-powered signal lights and self-ionising and grid-controlled flashtubes.—Amglo Corp., 4325 North Ravenswood Ave., Chicago 13, Ill.

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MATERIAL MIXER. 4-page brochure, Form 101, features Model SP1558, a portable meter-mixer for two-part compounds and adhesives.—Pyles Industries, Inc., 20855 Telegraph Rd., Detroit 41, Mich.

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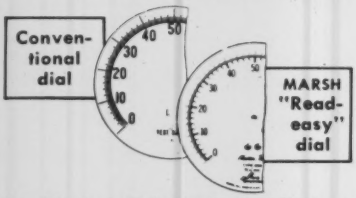

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product index

The following is a handy reference to products (and their reader-service number) reported in this issue. For more information on any product mentioned, circle the corresponding number on the reader-service card at the right.

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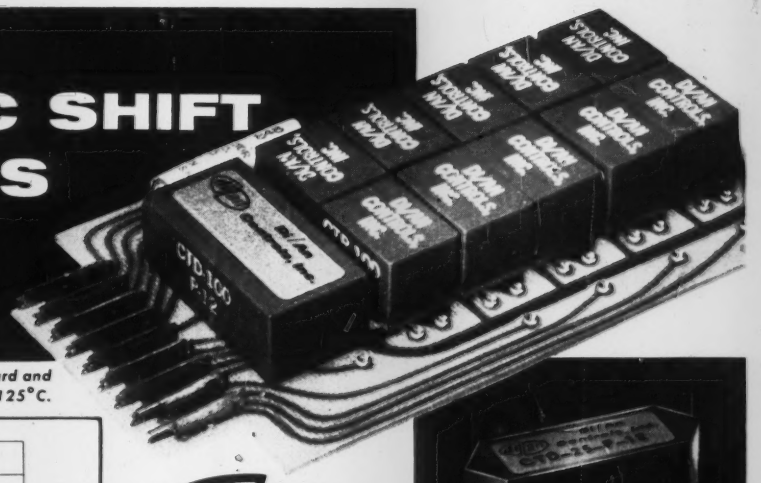
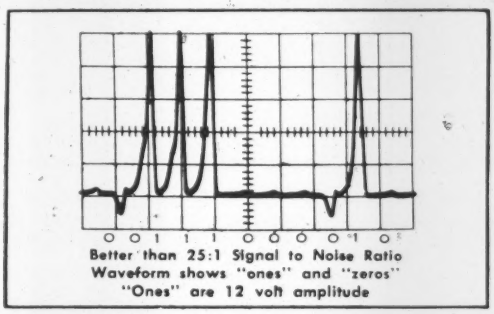


DI/AN Shift Registers are available in standard and special packages for environments up to 125°C.



Better than 25:1 Signal to Noise Ratio
Waveform shows "ones" and "zeros"
"Ones" are 12 volt amplitude

di an SRA-10

FLEXIBILITY: Available with solder lugs, pins and plug-in connectors.

Di/An Shift Registers have minimum 25:1 ONE:ZERO ratio output signal. These low power units have been proven by 4 years of product and field use to be most reliable. Available for rated operation in models from 10 to 400 KC, with plug-in connector, solder terminals, or rod for printed-wiring boards.

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This SRA-10 unit provides a compact, reliable register, flexible in application and available from stock. The SRA-10 units may be directly cascaded. The serial input and output are permanently wired on the printed wiring board. The voltage output of the tenth stage is also printed. Provisions are made to bring out the other parallel inputs and outputs.

All units operate from zero up to rated speed. The SRA-10 is a one core-per-bit register using a single phase clock. The SRA-10 is complete with power supply by-pass capacitor and mating plug-in connector.

Great system savings in power amplifiers and power supplies can be made by using the SRA-10. The low shift drive power, for example, permits 200 bits of register to be driven by 100 milliamperes with only a 5 volt peak drop across the series shift line. The compact SRA-10 unit fits in standard DI/AN housing 3½" high for 19" rack mounting. The housing has provision for twenty SRA-10 units. Test points and external connectors are supplied. This housing, which accepts up to 200 bits of storage, has a rack depth of 9".

The quality of Di/An products is the result of ten years' specialization in the design and application of magnetic shift register systems and components.

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Having put more shift register systems into applications than any other, Di/An knows the problems and moves efficiently towards their proper solution. Many problems can be solved quickly by the use of stock Di/An magnetic shift registers.

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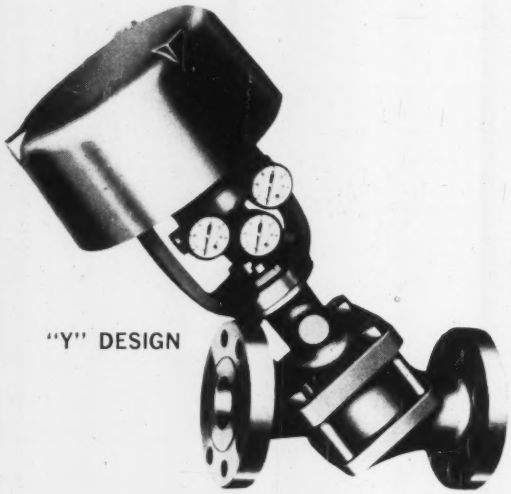
TWO NEW SPLIT-BODY VALVES

"S" DESIGN



"Y" DESIGN

BEST BY PRESENT AND FUTURE STANDARDS!

This new Hammel-Dahl "S" model starts out traditionally ...split-body, I.S.A. standards, slip-on flanges and retained, invertible seat ring ... but that's where similarity with other "S" types ends!

Greatest possible flow capacity combines with extended-stem guiding and travel length to give optimum flow control for the most demanding modern process.

Nominal Sizes: ½" to 10"

Body Configurations: "S" and "SL" (90° angle)

Body Ratings: 600 lb. ASA to 2500 lb. ASA

Connections: 150 to 2500 lb. ASA Flanged (Removable or Integral Flanges.) Screwed or welding ends.

Face-to-Face: I.S.A. Std. Also available in non-standard dimensions.

Materials: Cast Steel, Stainless Steel, Cast Iron, Nodular Iron, or any castable alloy.

YOUR CHOICE OF ACTUATORS: The Positioning Piston (shown) is one of more than 15 easily interchangeable actuator designs. Modes of actuation include:

- Pneumatic (Piston, Diaphragm, Isoforce)
- Electro-Hydraulic (Hydramotor)
- Electric (Tork-Master) or Manual.

The advanced new "Y" design incorporates I.S.A. standard face-to-face* dimensions, "S" valve travels and actuators. But it sets **new standards** for CV per nominal pipe size and for mechanical characteristics of fluid control. Straight-through flow eliminates hold-up and Cv's are **phenomenal** in every size.

Nominal Sizes: ½" to 10"

Body Configurations: "Y" and "YL" (45° angle)

Body Rating: 600 lb. ASA to 2500 lb. ASA

Connections: 150 to 2500 lb. ASA Flanged (Integral Flanges.) Screwed or welding ends.

***Face-to-Face:** I.S.A. Std. thru 4" size. Also available in non-standard dimensions.

Materials: Cast Steel, Stainless Steel, Cast Iron, Nodular Iron, or any castable alloy.

You can reduce costs with one of these new Split-Body designs. It's sure worth checking with the Hammel-Dahl Representative in your area. Call today.

Manufacturers of Control Valves and Allied Equipment

HAMMEL-DAHL DIVISION

GENERAL CONTROLS

Warwick Industrial Park, Warwick, Rhode Island

Representatives in Principal Cities of United States, Canada and Europe

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